TDWR Interface Control and Specifications Documentation for the NWS Supplemental Product Generator

National Oceanic and Atmospheric Administration
National Weather Service
Office of Science &Technology Systems Engineering Center

August 3, 2005
Version 4.3

Principal Contributors

NOAA/National Weather Service, Systems Engineering Center
Michael Istok
Warren Blanchard

Mitretek Systems, Inc.
Andrew Stern
Robert Saffle

RS Information Systems, Inc.
Brian Klein
Ning Shen

Contents

TDWR Specifications

The Terminal Doppler Weather Radar (TDWR) is a high quality, dedicated meteorological surveillance radar deployed near many of the larger airports in the U.S. As such, the TDWR is usually located close to large population centers, mainly over the eastern half of the country (Figure 1).

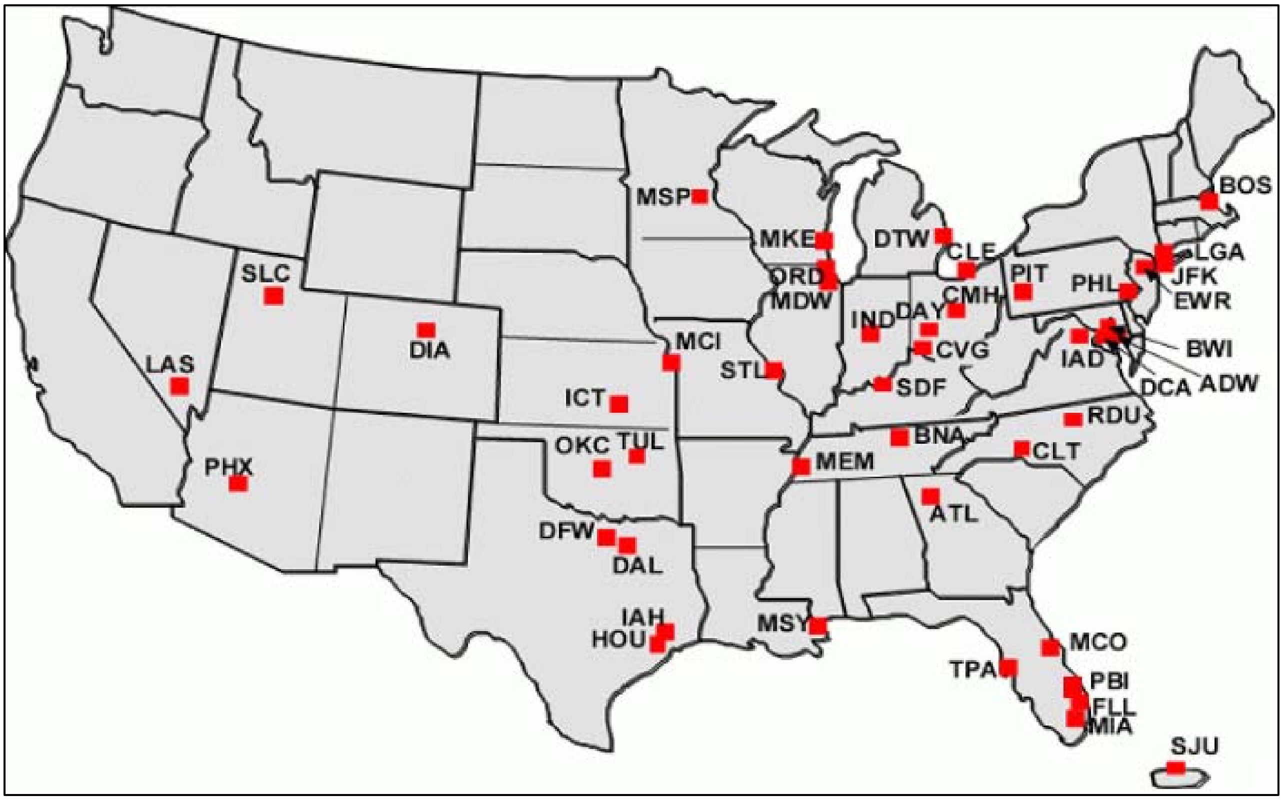

Figure 1 – Distribution of the 45 operational TDWR systems around the country

The range resolution of the TDWR is finer than what is available in the Weather Surveillance Radar, 1988 Doppler (WSR-88D) or any other FAA radar that has weather channel capability. The TDWR utilizes a range gate resolution of 150 meters (m) for Doppler data. It has a resolution of 150 m for reflectivity data within 135 kilometers (km) and 300 m from beyond 135 km to 460 km. By contrast, the WSR-88D employed by the National Weather Service (NWS), Federal Aviation Administration (FAA) and Department of Defense (DoD) has a maximum range gate resolution of 250 m for Doppler and 1 km for surveillance data.

The angular (azimuth) resolution of the TDWR is nearly twice what is available in the WSR-88D. Each radial in the TDWR has a beam width of 0.55 degrees. The average beam width for the WSR-88D is 0.95 degrees. However, a lack of processing power and communications throughput in the original TDWR Radar Data Acquisition (RDA) component spoils the resolution to 1.0 degree for all radials. A modernization of the TDWR RDA is expected during the next couple of years, which may allow full resolution data to become available.

The C-Band wavelength of the TDWR makes its signal more susceptible to beam attenuation, velocity aliasing and range folding than the S-Band WSR-88D. In order to minimize the obscuration caused by multiple trip echoes, the TDWR uses multiple Pulse Repetition Frequencies (PRFs) and a strategy of including a long-range scan for each set of short range elevations. This along with quality control algorithms provides dealiased velocity data out to 90 km (48 nm) within a range of –80 to +80 meters/second (m/s).

Finally, TDWR angles are reported in degrees east of magnetic north as compared to true north for the WSR-88D. Table 1 shows a comparison of technical specifications between the TDWR and the WSR-88D.

Table 1 - Comparison of TDWR and WSR-88D technical specifications

	TDWR	**WSR-88D**
Antenna		
Peak Power	250 KW	750 KW
Beam Width	0.55 Degrees (spoiled to 1 Degree)	0.95 Degrees (on average)
Power Gain	50 dB	45.5 dB
Minimum Elevation	0 Degrees	0.5 Degrees
Maximum Elevation	60 Degrees	19.5 Degrees
Maximum Rotation Rate	5 RPM	6 RPM
Transmitter		
Frequency	C Band	S Band
Wavelength	5.3 cm	10.5 cm
Pulse Width Max	1.1 msec 1.1 msec	1.57 msec 4.70 msec
Polarization	Linear Horizontal	Linear Horizontal
Maximum Reflectivity Range	460 km	460 km
Minimum Unambiguous Doppler Range	90 km	115 km
Maximum Doppler Range	90 km	230 km
Range Resolution (Reflectivity)	150 m (out to 135 km) 300 m (135 km – 460 km)	1 km
Range Resolution (Doppler)	150 m	250 m
Scan Strategies		
Clear Air/Monitor Mode	Scan Time: 6 min	Scan Time: 6 – 10 min
	Number of Scans: 17	Number of Scans: 5
Severe/Hazardous Mode	Scan Time: 6 min	Scan Time: 5 min
	Number of Scans: 23	Number of Scans: 9 - 14

Areal Coverage

TDWR systems were specifically placed to sample a three dimensional volume over its associated airport runways, and its immediate approach and departure routes. Its scanning strategies and algorithms are optimized to detect wind shear and downburst signatures.

However, for NWS field office operations, the TDWR offers a unique opportunity to simultaneously observe hydrometeors and storm structure from different angles and a different wavelength. Figure 2 displays the distribution of TDWR systems over the continental U.S. with their 90 km scans.

TDWR Doppler coverage is particularly good over portions of the Ohio River Valley. However, there are several regions where there is significant overlap, such as the northeast corridor from metropolitan Washington to New York, along the Gold Coast of Florida, over metro Chicago and the Dallas/Fort Worth Metroplex. Figure 3 provides a close-up view of the overlap of the urban northeast.

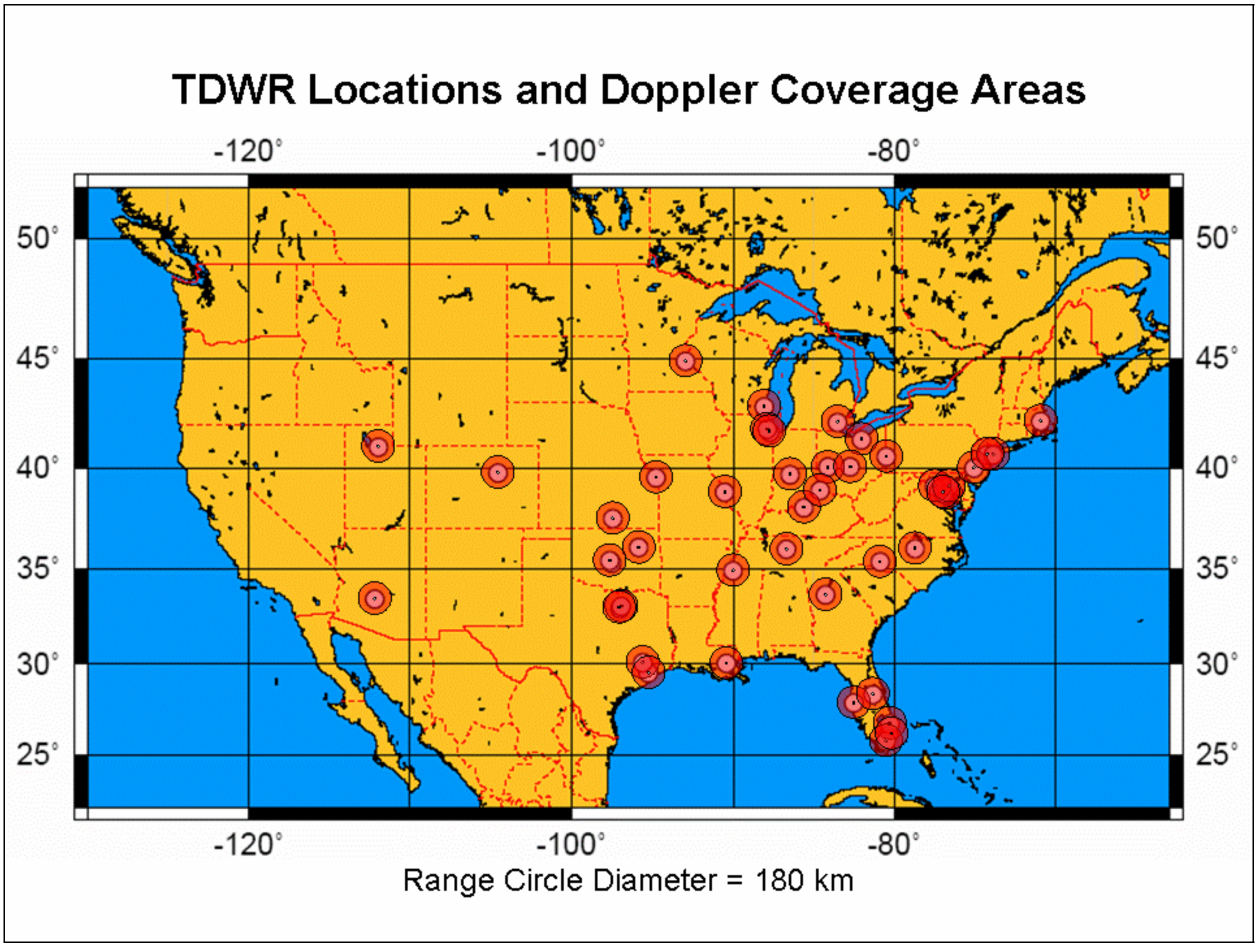

Figure 2 - TDWR Surveillance and Doppler coverage areas over the continental U.S. (90 km radius)

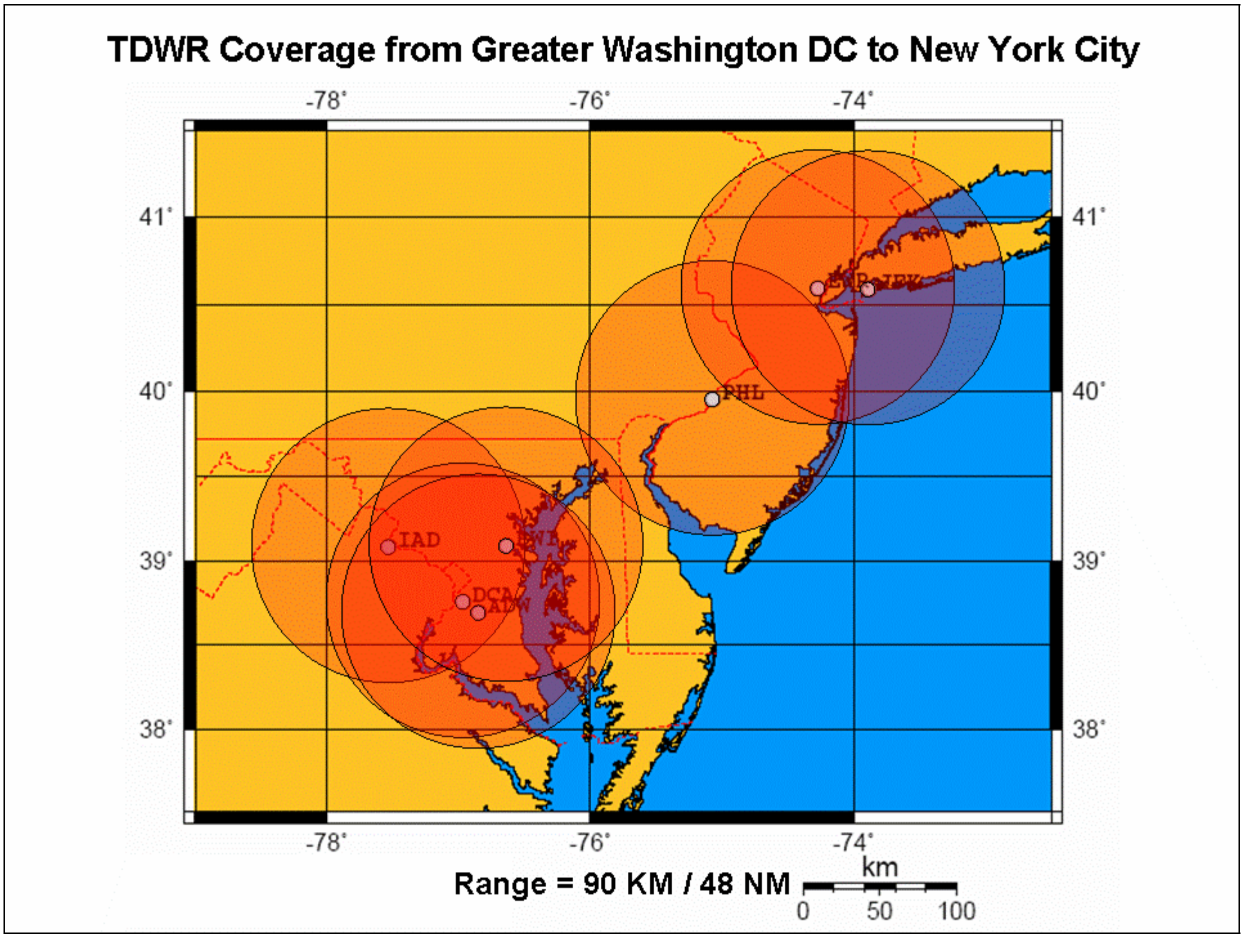

Figure 3 – Significant overlapping TDWR coverage (90 km range) from metro Washington to New York. Radar IDs: IAD=Dulles, DCA=Washington National, ADW=Andrews Air Force Base, BWI=Baltimore, PHL=Philadelphia, EWR=Newark, JFK=Kennedy.

TDWR Scanning Strategies

Like the WSR-88D, the TDWR scan strategy consists of two operational modes. Analogous to the WSR-88D "clear air mode", the TDWR has the "monitor mode". Precipitation mode in the TDWR is called "hazardous mode". When originally deployed, the TDWR utilized a combination of 360-degree sweeps interlaced with 120-degree sector scans in hazardous mode to save processing. This strategy was replaced by early 2004 with full 360-degree strategies.

While the TDWR recognizes the concept of a volume in a similar fashion as the WSR-88D, there are still significant differences in the scanning strategies between the radar systems. With respect to the TDWR, some of these differences include:

1. More sweeps per scan sequence (23 in hazardous mode)
2. Maximum elevation angle to 60 degrees (in monitor mode)
3. Numerous repeated patterns and elevations within one volume (in hazardous mode)
4. Repeated base elevation (less than 1 degree) every minute (in hazardous mode)
5. Each radar can have a different set of elevation angles depending on the distance between the TDWR and its associated airport (in both modes).

TDWR Monitor Mode

Monitor mode is used to survey the weather in all directions and determine if more frequent scans over the airport are necessary (which entails switching to hazardous mode). Monitor mode consists of numerous scans ranging from its base elevation (which is always less than 1.0 degree) up to a maximum of 60 degrees.

All monitor mode strategies contain 17 elevations. Similar to the WSR-88D, the TDWR employs a split-cut strategy at low elevation angles (two scans at the same elevation angle but with different PRF). Unlike the WSR-88D, the TDWR antenna does not always sequentially move from lowest to highest elevation. Instead, the antenna can take multiple low elevation scans before ascending in sequential order to its upper scans. Figure 4 provides a summary example of monitor mode strategies for the 45 operational TDWR systems.

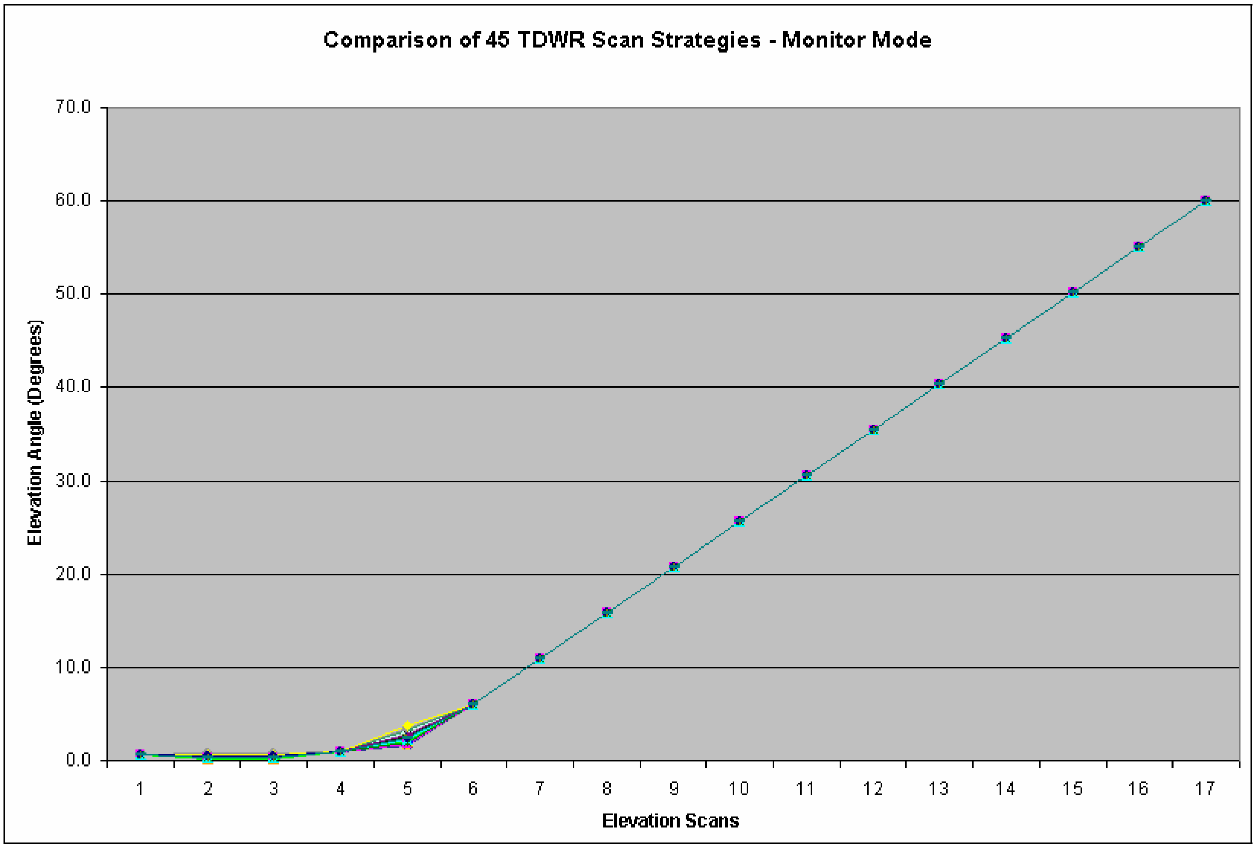

Figure 4 – Comparing elevation angles (vertical axis) of the 17 scans (horizontal axis) within the monitor mode for 45 TDWR radars. The only differences in strategies are found in the lower elevations.

As a specific example of one monitor mode scan strategy, the Baltimore TDWR (BWI) is shown in Figure 5. The first scan in a monitor mode contains a long range (460 km) surveillance cut. All remaining scans have a maximum range of 90 km (with truncation at 70,000 feet).

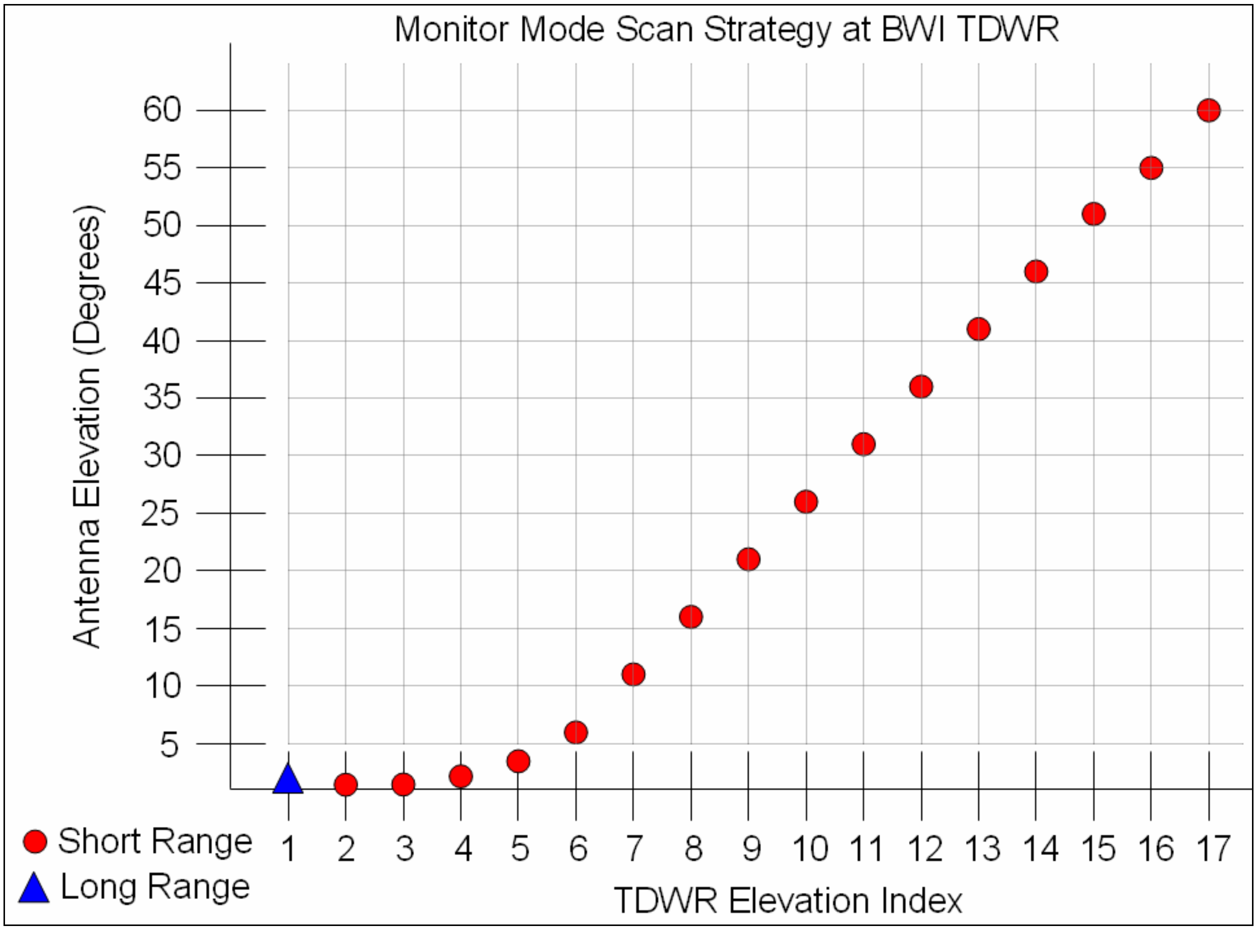

Figure 5 – Monitor mode scan strategy for the BWI TDWR

The TDWR antenna always rotates in a clockwise direction. In monitor mode, the rotation speed has a constant rate of 19 degrees/second (d/s) or 3.2 revolutions/minute (rpm).

The TDWR uses the first several cuts to obtain clutter mitigation and velocity folding information. The first cut is used only for long range surveillance (PRI of 3066 microseconds). The second and third cuts are used to initialize wind field models for the dealiasing algorithm. The first dealiased velocity information becomes available in cut 3 and is available in all remaining scans.

Other scans in monitor mode are used for severe weather surveillance. Cuts 5 through 17 (inclusive) are used to search for microburst signatures that may be aloft. Cut 3 is used to determine if a microburst signature is close to the surface.

Table 2 - TDWR station identifiers, their associated NWS Weather Forecast Offices (WFOs) and the elevation angle of each cut within **monitor mode**.

STN	WFO	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
ADW	LWX	0.6	0.3	0.3	1.0	2.7	6.1	11.0	15.9	20.8	25.7	30.6	35.5	40.4	45.3	50.2	55.1	60.0
ATL	FFC	0.6	0.3	0.3	1.0	2.4	6.1	11.0	15.9	20.8	25.7	30.6	35.5	40.4	45.3	50.2	55.1	60.0
BNA	OHX	0.6	0.4	0.4	1.0	2.2	6.1	11.0	15.9	20.8	25.7	30.6	35.5	40.4	45.3	50.2	55.1	60.0
BOS	BOX	0.6	0.3	0.3	1.0	1.6	6.1	11.0	15.9	20.8	25.7	30.6	35.5	40.4	45.3	50.2	55.1	60.0
BWI	LWX	0.6	0.5	0.5	1.0	3.3	6.1	11.0	15.9	20.8	25.7	30.6	35.5	40.4	45.3	50.2	55.1	60.0
CLE	CLE	0.6	0.2	0.2	1.0	2.1	6.1	11.0	15.9	20.8	25.7	30.6	35.5	40.4	45.3	50.2	55.1	60.0
CLT	GSP	0.6	0.2	0.2	1.0	2.4	6.1	11.0	15.9	20.8	25.7	30.6	35.5	40.4	45.3	50.2	55.1	60.0
CMH	ILN	0.6	0.1	0.1	1.0	2.2	6.1	11.0	15.9	20.8	25.7	30.6	35.5	40.4	45.3	50.2	55.1	60.0
CVG	ILN	0.6	0.1	0.1	1.0	2.1	6.1	11.0	15.9	20.8	25.7	30.6	35.5	40.4	45.3	50.2	55.1	60.0
DAL	FWD	0.6	0.5	0.5	1.0	3.1	6.1	11.0	15.9	20.8	25.7	30.6	35.5	40.4	45.3	50.2	55.1	60.0
DAY	ILN	0.6	0.3	0.3	1.0	2.4	6.1	11.0	15.9	20.8	25.7	30.6	35.5	40.4	45.3	50.2	55.1	60.0
DCA	LWX	0.6	0.3	0.3	1.0	2.6	6.1	11.0	15.9	20.8	25.7	30.6	35.5	40.4	45.3	50.2	55.1	60.0
DEN	BOU	0.6	0.3	0.3	1.0	2.5	6.1	11.0	15.9	20.8	25.7	30.6	35.5	40.4	45.3	50.2	55.1	60.0
DFW	FWD	0.6	0.4	0.4	1.0	1.8	6.1	11.0	15.9	20.8	25.7	30.6	35.5	40.4	45.3	50.2	55.1	60.0
DTW	DTX	0.6	0.1	0.1	1.0	2.1	6.1	11.0	15.9	20.8	25.7	30.6	35.5	40.4	45.3	50.2	55.1	60.0
EWR	PHI	0.6	0.3	0.3	1.0	2.7	6.1	11.0	15.9	20.8	25.7	30.6	35.5	40.4	45.3	50.2	55.1	60.0
FLL	MFL	0.6	0.3	0.3	1.0	1.9	6.1	11.0	15.9	20.8	25.7	30.6	35.5	40.4	45.3	50.2	55.1	60.0
HOU	HGX	0.6	0.2	0.2	1.0	2.6	6.1	11.0	15.9	20.8	25.7	30.6	35.5	40.4	45.3	50.2	55.1	60.0
IAD	LWX	0.6	0.3	0.3	1.0	2.1	6.1	11.0	15.9	20.8	25.7	30.6	35.5	40.4	45.3	50.2	55.1	60.0
IAH	HGX	0.6	0.1	0.1	1.0	1.6	6.1	11.0	15.9	20.8	25.7	30.6	35.5	40.4	45.3	50.2	55.1	60.0
ICT	ICT	0.6	0.2	0.2	1.0	2.4	6.1	11.0	15.9	20.8	25.7	30.6	35.5	40.4	45.3	50.2	55.1	60.0
IND	IND	0.6	0.3	0.3	1.0	2.5	6.1	11.0	15.9	20.8	25.7	30.6	35.5	40.4	45.3	50.2	55.1	60.0
JFK	OKX	0.6	0.5	0.5	1.0	2.8	6.1	11.0	15.9	20.8	25.7	30.6	35.5	40.4	45.3	50.2	55.1	60.0
LAS	VEF	0.6	0.8	0.8	1.0	3.4	6.1	11.0	15.9	20.8	25.7	30.6	35.5	40.4	45.3	50.2	55.1	60.0
MCI	EAX	0.6	0.3	0.3	1.0	1.8	6.1	11.0	15.9	20.8	25.7	30.6	35.5	40.4	45.3	50.2	55.1	60.0
MCO	MLB	0.6	0.3	0.3	1.0	3.3	6.1	11.0	15.9	20.8	25.7	30.6	35.5	40.4	45.3	50.2	55.1	60.0
MDW	LOT	0.6	0.3	0.3	1.0	2.6	6.1	11.0	15.9	20.8	25.7	30.6	35.5	40.4	45.3	50.2	55.1	60.0
MEM	MEG	0.6	0.3	0.3	1.0	2.3	6.1	11.0	15.9	20.8	25.7	30.6	35.5	40.4	45.3	50.2	55.1	60.0
MIA	MFL	0.6	0.2	0.2	1.0	1.9	6.1	11.0	15.9	20.8	25.7	30.6	35.5	40.4	45.3	50.2	55.1	60.0
MKE	MKX	0.6	0.3	0.3	1.0	2.0	6.1	11.0	15.9	20.8	25.7	30.6	35.5	40.4	45.3	50.2	55.1	60.0
MSP	MPX	0.6	0.3	0.3	1.0	1.7	6.1	11.0	15.9	20.8	25.7	30.6	35.5	40.4	45.3	50.2	55.1	60.0
MSY	LIX	0.6	0.3	0.3	1.0	2.7	6.1	11.0	15.9	20.8	25.7	30.6	35.5	40.4	45.3	50.2	55.1	60.0
OKC	OUN	0.6	0.5	0.5	1.0	2.5	6.1	11.0	15.9	20.8	25.7	30.6	35.5	40.4	45.3	50.2	55.1	60.0
ORD	LOT	0.6	0.3	0.3	1.0	1.9	6.1	11.0	15.9	20.8	25.7	30.6	35.5	40.4	45.3	50.2	55.1	60.0
PBI	MFL	0.6	0.1	0.1	1.0	2.1	6.1	11.0	15.9	20.8	25.7	30.6	35.5	40.4	45.3	50.2	55.1	60.0
PHL	PHI	0.6	0.4	0.4	1.0	2.0	6.1	11.0	15.9	20.8	25.7	30.6	35.5	40.4	45.3	50.2	55.1	60.0
PHX	PSR	0.6	0.6	0.6	1.0	3.7	6.1	11.0	15.9	20.8	25.7	30.6	35.5	40.4	45.3	50.2	55.1	60.0
PIT	PBZ	0.6	0.3	0.3	1.0	1.8	6.1	11.0	15.9	20.8	25.7	30.6	35.5	40.4	45.3	50.2	55.1	60.0
RDU	RAH	0.6	0.3	0.3	1.0	2.3	6.1	11.0	15.9	20.8	25.7	30.6	35.5	40.4	45.3	50.2	55.1	60.0
SDF	LMK	0.6	0.3	0.3	1.0	2.0	6.1	11.0	15.9	20.8	25.7	30.6	35.5	40.4	45.3	50.2	55.1	60.0
SJU	SJU	0.6	0.3	0.3	1.0	2.0	6.1	11.0	15.9	20.8	25.7	30.6	35.5	40.4	45.3	50.2	55.1	60.0
SLC	SLC	0.6	0.5	0.5	1.0	2.4	6.1	11.0	15.9	20.8	25.7	30.6	35.5	40.4	45.3	50.2	55.1	60.0
STL	LSX	0.6	0.3	0.3	1.0	2.7	6.1	11.0	15.9	20.8	25.7	30.6	35.5	40.4	45.3	50.2	55.1	60.0
TPA	TBW	0.6	0.3	0.3	1.0	2.7	6.1	11.0	15.9	20.8	25.7	30.6	35.5	40.4	45.3	50.2	55.1	60.0
TUL	TSA	0.6	0.3	0.3	1.0	2.4	6.1	11.0	15.9	20.8	25.7	30.6	35.5	40.4	45.3	50.2	55.1	60.0

TDWR Hazardous Mode

The TDWR automatically switches from monitor mode to hazardous mode when one of two conditions occurs within the principal coverage area of its associated airport. Either a region of 30 dBZ must be located within 24.3 nautical miles (nm) of its associated airport with a nominal extent of 1.3 nm and be at least 1.3 nm above ground level (AGL), or a hazardous wind condition (such as a wind shear or microburst signature) has been detected.

The TDWR hazardous mode has been optimized to monitor both low and high level conditions over and in proximity to its associated airport. In this mode, a base (low elevation) scan is required approximately every minute to monitor for possible low-level wind shear. A long-range scan is required once at the start of each new scanning strategy for range folding mitigation.

Each complete hazardous mode scan strategy contains 23 elevations. Elevation angles can be different for each TDWR. However, in general, the strategy patterns (aloft or low level scans) are the same among all systems. A summary image of all 45 TDWR hazardous mode strategies can be found in Figure 6.

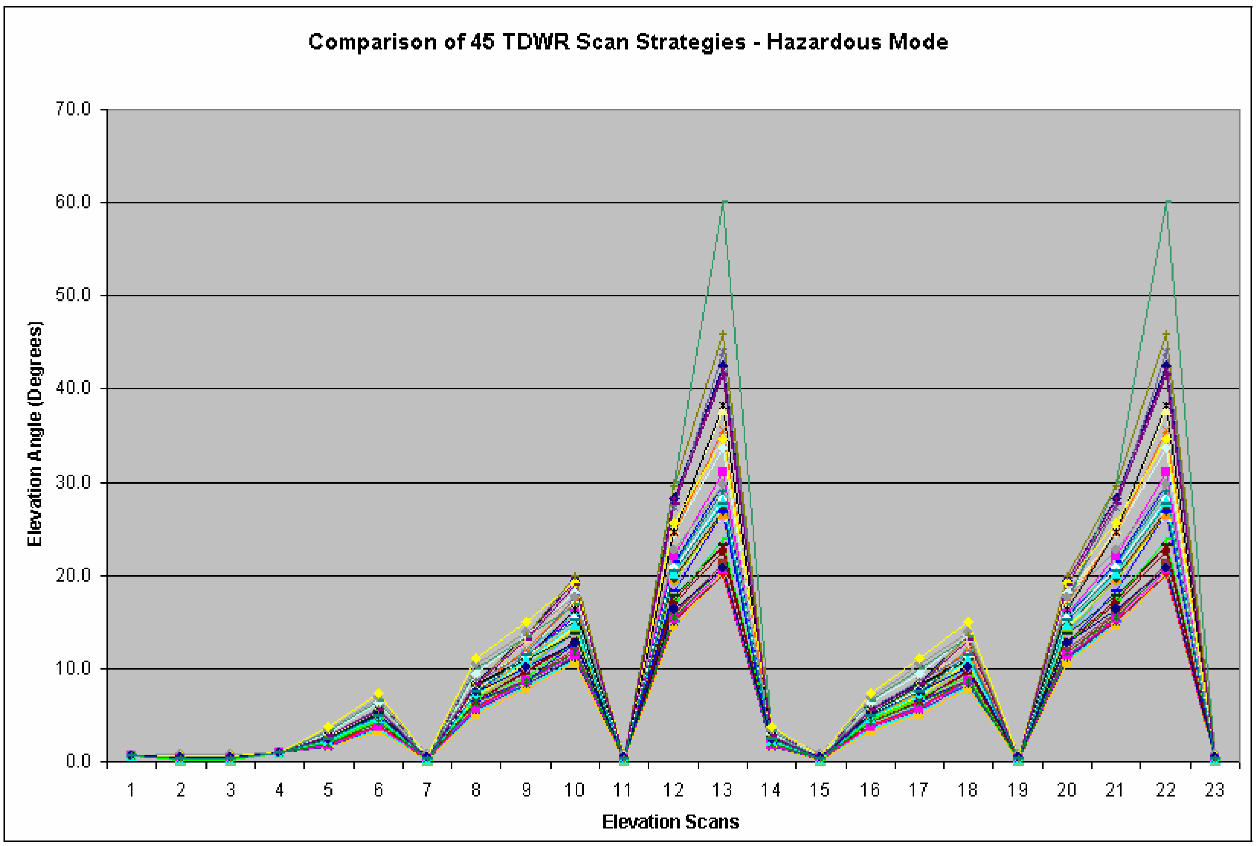

Figure 6 – Hazardous mode scan strategies for all 45 TDWR systems. The horizontal axis shows the cut number. The vertical axis shows the elevation angle.

Because of the placement of each TDWR to its associated airport, elevation angles for any particular cut can have a wide range. For example, aloft scans (cut 13 from Figure 6) can range from 14 degrees to 60 degrees at different stations.

The hazardous mode scan strategy consists of three distinct parts. As in the monitor mode strategy, the first several cuts are used for clutter mitigation and unfolding. The remaining cuts are divided into two identical "sub-volumes", each with a low elevation scan once per minute and aloft scans. Figure 7 shows an example of hazardous mode for BWI.

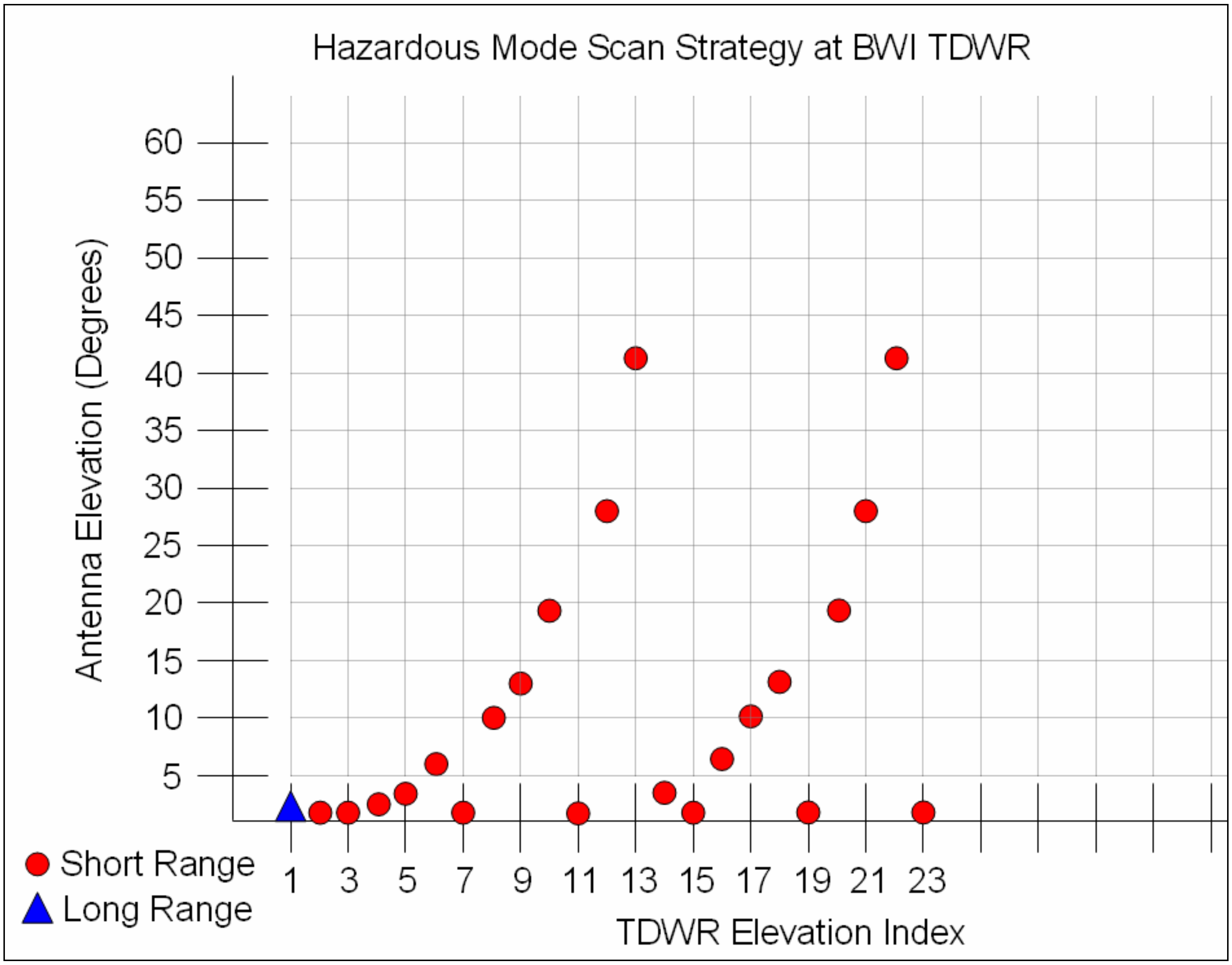

Figure 7 – Hazardous Mode Scan Strategy at BWI

Hazardous mode requires just about the same amount of time to complete as monitor mode because it uses a higher antenna rotation rate. While not the same at all radars, the scan strategy uses a mix of rotation rates from 21.6 d/s (3.6 rpm) to 30 d/s (5 rpm).

Similar to monitor mode, there is no velocity data available on the long range surveillance scan (cut 1) and cuts 2 and 3 are used to initialize a wind model for dealiasing. The first dealiased velocity data are available in cut 3. Microburst aloft scanning is performed at all remaining cuts except for the low elevation scans (where low elevation microburst identification is done).

Table 3 - TDWR station identifiers, their associated NWS WFOs and the elevation angle of each cut within **hazardous mode**.

STN	WFO	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
ADW	LWX	0.6	0.3	0.3	1.0	2.7	5.6	0.3	8.5	13.5	19.5	0.3	28.3	42.5	2.7	0.3	5.6	8.5	13.5	0.3	19.5	28.3	42.5	0.3
ATL	FFC	0.6	0.3	0.3	1.0	2.4	4.9	0.3	7.4	11.5	15.9	0.3	22.1	31.1	2.4	0.3	4.9	7.4	11.5	0.3	15.9	22.1	31.1	0.3
BNA	OHX	0.6	0.4	0.4	1.0	2.2	4.7	0.4	7.1	10.7	14.4	0.4	19.5	26.5	2.2	0.4	4.7	7.1	10.7	0.4	14.4	19.5	26.5	0.4
BOS	BOX	0.6	0.3	0.3	1.0	1.6	3.5	0.3	5.4	8.0	10.9	0.3	14.8	20.1	1.6	0.3	3.5	5.4	8.0	0.3	10.9	14.8	20.1	0.3
BWI	LWX	0.6	0.5	0.5	1.0	3.3	6.6	0.5	10.0	13.4	19.4	0.5	28.1	42.0	3.3	0.5	6.6	10.0	13.4	0.5	19.4	28.1	42.0	0.5
CLE	CLE	0.6	0.2	0.2	1.0	2.1	4.3	0.2	6.6	9.7	12.8	0.2	17.0	22.6	2.1	0.2	4.3	6.6	9.7	0.2	12.8	17.0	22.6	0.2
CLT	GSP	0.6	0.2	0.2	1.0	2.4	5.0	0.2	7.7	11.5	15.6	0.2	21.2	29.1	2.4	0.2	5.0	7.7	11.5	0.2	15.6	21.2	29.1	0.2
CMH	ILN	0.6	0.1	0.1	1.0	2.2	4.8	0.1	7.4	11.4	15.6	0.1	21.5	29.8	2.2	0.1	4.8	7.4	11.4	0.1	15.6	21.5	29.8	0.1
CVG	ILN	0.6	0.1	0.1	1.0	2.1	4.4	0.1	6.6	10.2	13.9	0.1	19.0	26.1	2.1	0.1	4.4	6.6	10.2	0.1	13.9	19.0	26.1	0.1
DAL	FWD	0.6	0.5	0.5	1.0	3.1	6.3	0.5	9.5	13.5	18.1	0.5	24.6	33.7	3.1	0.5	6.3	9.5	13.5	0.5	18.1	24.6	33.7	0.5
DAY	ILN	0.6	0.3	0.3	1.0	2.4	4.9	0.3	7.4	10.8	14.5	0.3	19.4	26.1	2.4	0.3	4.9	7.4	10.8	0.3	14.5	19.4	26.1	0.3
DCA	LWX	0.6	0.3	0.3	1.0	2.6	5.7	0.3	8.7	11.7	17.2	0.3	25.1	37.7	2.6	0.3	5.7	8.7	11.7	0.3	17.2	25.1	37.7	0.3
DEN	BOU	0.6	0.3	0.3	1.0	2.5	5.2	0.3	8.0	10.8	13.9	0.3	18.2	24.0	2.5	0.3	5.2	8.0	10.8	0.3	13.9	18.2	24.0	0.3
DFW	FWD	0.6	0.4	0.4	1.0	1.8	3.8	0.4	5.7	7.7	10.7	0.4	14.7	20.1	1.8	0.4	3.8	5.7	7.7	0.4	10.7	14.7	20.1	0.4
DTW	DTX	0.6	0.1	0.1	1.0	2.1	4.4	0.1	6.7	10.0	13.7	0.1	18.9	26.1	2.1	0.1	4.4	6.7	10.0	0.1	13.7	18.9	26.1	0.1
EWR	PHI	0.6	0.3	0.3	1.0	2.7	5.6	0.3	8.4	12.9	17.8	0.3	24.6	34.6	2.7	0.3	5.6	8.4	12.9	0.3	17.8	24.6	34.6	0.3
FLL	MFL	0.6	0.3	0.3	1.0	1.9	4.0	0.3	6.1	8.3	11.3	0.3	15.1	20.1	1.9	0.3	4.0	6.1	8.3	0.3	11.3	15.1	20.1	0.3
HOU	HGX	0.6	0.2	0.2	1.0	2.6	5.3	0.2	8.0	11.9	15.8	0.2	21.1	28.4	2.6	0.2	5.3	8.0	11.9	0.2	15.8	21.1	28.4	0.2
IAD	LWX	0.6	0.3	0.3	1.0	2.1	4.4	0.3	6.7	10.3	14.1	0.3	19.4	26.9	2.1	0.3	4.4	6.7	10.3	0.3	14.1	19.4	26.9	0.3
IAH	HGX	0.6	0.1	0.1	1.0	1.6	3.3	0.1	5.1	7.8	10.7	0.1	14.6	20.1	1.6	0.1	3.3	5.1	7.8	0.1	10.7	14.6	20.1	0.1
ICT	ICT	0.6	0.2	0.2	1.0	2.4	4.9	0.2	7.4	11.1	14.8	0.2	19.8	26.7	2.4	0.2	4.9	7.4	11.1	0.2	14.8	19.8	26.7	0.2
IND	IND	0.6	0.3	0.3	1.0	2.5	5.1	0.3	7.8	12.1	17.2	0.3	24.5	35.7	2.5	0.3	5.1	7.8	12.1	0.3	17.2	24.5	35.7	0.3
JFK	OKX	0.6	0.5	0.5	1.0	2.8	5.7	0.5	8.7	11.6	17.7	0.5	27.3	44.0	2.8	0.5	5.7	8.7	11.6	0.5	17.7	27.3	44.0	0.5
LAS	VEF	0.6	0.8	0.8	1.0	3.4	6.9	0.8	10.4	13.9	17.6	0.8	22.8	29.8	3.4	0.8	6.9	10.4	13.9	0.8	17.6	22.8	29.8	0.8
MCI	EAX	0.6	0.3	0.3	1.0	1.8	3.7	0.3	5.6	8.4	11.2	0.3	15.0	20.1	1.8	0.3	3.7	5.6	8.4	0.3	11.2	15.0	20.1	0.3
MCO	MLB	0.6	0.3	0.3	1.0	3.3	6.6	0.3	10.0	13.4	16.8	0.3	29.9	60.0	3.3	0.3	6.6	10.0	13.4	0.3	16.8	29.9	60.0	0.3
MDW	LOT	0.6	0.3	0.3	1.0	2.6	5.3	0.3	8.1	10.9	13.8	0.3	17.8	23.3	2.6	0.3	5.3	8.1	10.9	0.3	13.8	17.8	23.3	0.3
MEM	MEG	0.6	0.3	0.3	1.0	2.3	4.7	0.3	7.2	10.9	14.7	0.3	19.8	27.0	2.3	0.3	4.7	7.2	10.9	0.3	14.7	19.8	27.0	0.3
MIA	MFL	0.6	0.2	0.2	1.0	1.9	3.9	0.2	5.9	8.8	11.8	0.2	15.8	21.2	1.9	0.2	3.9	5.9	8.8	0.2	11.8	15.8	21.2	0.2
MKE	MKX	0.6	0.3	0.3	1.0	2.0	4.3	0.3	6.5	8.8	12.1	0.3	16.0	21.3	2.0	0.3	4.3	6.5	8.8	0.3	12.1	16.0	21.3	0.3
MSP	MPX	0.6	0.3	0.3	1.0	1.7	3.7	0.3	5.6	8.4	11.3	0.3	15.0	20.1	1.7	0.3	3.7	5.6	8.4	0.3	11.3	15.0	20.1	0.3
MSY	LIX	0.6	0.3	0.3	1.0	2.7	5.5	0.3	8.3	11.1	16.4	0.3	24.7	38.3	2.7	0.3	5.5	8.3	11.1	0.3	16.4	24.7	38.3	0.3
OKC	OUN	0.6	0.5	0.5	1.0	2.5	5.1	0.5	7.7	11.3	15.3	0.5	20.7	28.2	2.5	0.5	5.1	7.7	11.3	0.5	15.3	20.7	28.2	0.5
ORD	LOT	0.6	0.3	0.3	1.0	1.9	3.9	0.3	5.9	8.7	11.5	0.3	15.2	20.1	1.9	0.3	3.9	5.9	8.7	0.3	11.5	15.2	20.1	0.3

PBI	MFL	0.6	0.1	0.1	1.0	2.1	4.5	0.1	6.8	9.1	12.7	0.1	17.4	23.8	2.1	0.1	4.5	6.8	9.1	0.1	12.7	17.4	23.8	0.1
PHL	PHI	0.6	0.4	0.4	1.0	2.0	4.3	0.4	6.5	8.7	12.7	0.4	18.3	26.8	2.0	0.4	4.3	6.5	8.7	0.4	12.7	18.3	26.8	0.4
PHX	PSR	0.6	0.6	0.6	1.0	3.7	7.4	0.6	11.2	15.0	19.3	0.6	25.7	34.7	3.7	0.6	7.4	11.2	15.0	0.6	19.3	25.7	34.7	0.6
PIT	PBZ	0.6	0.3	0.3	1.0	1.8	3.7	0.3	5.7	8.6	11.4	0.3	15.3	20.6	1.8	0.3	3.7	5.7	8.6	0.3	11.4	15.3	20.6	0.3
RDU	RAH	0.6	0.3	0.3	1.0	2.3	4.8	0.3	7.2	10.9	14.8	0.3	20.3	27.9	2.3	0.3	4.8	7.2	10.9	0.3	14.8	20.3	27.9	0.3
SDF	LMK	0.6	0.3	0.3	1.0	2.0	4.3	0.3	6.6	9.8	13.0	0.3	17.4	23.3	2.0	0.3	4.3	6.6	9.8	0.3	13.0	17.4	23.3	0.3
SJU	SJU	0.6	0.3	0.3	1.0	2.0	4.2	0.3	6.4	8.6	11.7	0.3	15.6	20.9	2.0	0.3	4.2	6.4	8.6	0.3	11.7	15.6	20.9	0.3
SLC	SLC	0.6	0.5	0.5	1.0	2.4	5.0	0.5	7.6	10.2	12.8	0.5	16.3	20.7	2.4	0.5	5.0	7.6	10.2	0.5	12.8	16.3	20.7	0.5
STL	LSX	0.6	0.3	0.3	1.0	2.7	5.5	0.3	8.3	13.5	19.9	0.3	29.6	46.0	2.7	0.3	5.5	8.3	13.5	0.3	19.9	29.6	46.0	0.3
TPA	TBW	0.6	0.3	0.3	1.0	2.7	5.5	0.3	8.3	13.1	18.9	0.3	27.6	41.5	2.7	0.3	5.5	8.3	13.1	0.3	18.9	27.6	41.5	0.3
TUL	TSA	0.6	0.3	0.3	1.0	2.4	4.9	0.3	7.5	11.4	15.2	0.3	20.4	27.7	2.4	0.3	4.9	7.5	11.4	0.3	15.2	20.4	27.7	0.3

Volume Coverage Patterns for use in NWS Operations

This section specifies how the TDWR scan strategy interpretation has been modified for use in NWS operations. Up until now, all mention of TDWR scans have been in the forms of scanning modes or strategies. The concept of a Volume Coverage Pattern (VCP) can now be introduced since the Supplemental Product Generator (SPG) that processes TDWR data is a modified NEXRAD Radar Product Generator (RPG). All output from the SPG is sent to AWIPS workstations using compliant formats that are used for the WSR-88D.

The WSR-88D term VCP is used to describe the translation of TDWR scan strategies. Since the main distinction between TDWR monitor and hazardous mode is the presence of significant weather near it associated airport, and not the existence of hazardous weather anywhere under its radar umbrella, both TDWR VCPs have been assigned to the “Precipitation/Severe Weather” Operational Mode within the SPG.

The VCP translation of the TDWR monitor mode scan strategy will be referred as VCP 90 within the SPG and AWIPS. The VCP translation of the TDWR hazardous mode scan strategy will be referred to as VCP 80. Descriptions of each VCP are provided below.

VCP 90 Description

Figure 8 contains the VCP translation of the monitor mode scan strategy using elevation angles from the BWI TDWR as an example. The translation of monitor mode to VCP 90 yields 16 actual scans.

Elevation cut 2 in VCP 90 is actually a combination of data moments from TDWR monitor mode cuts 2 and 3. Since there is no dealiased Doppler data available from cut 2, but the surveillance data benefits from a lower PRI, surveillance data from TDWR cut 2 (as shown with a red circle around the R) has been used in VCP 90 elevation 2. The first dealiased Doppler data becomes available in TDWR cut 3. The Doppler moments (velocity and spectrum width as shown with red circles around V and W) have been used in VCP 90 elevation 2. The newly formed VCP 90 elevation 2 becomes available from the SPG at the completion of TDWR elevation 3.

Within Figure 8, the left half represents the native data stream from the TDWR. The TDWR monitor mode contains 17 actual scans. The “Elv” column represents the elevation angle of each cut in tenths of a degree. As with the WSR-88D, the TDWR generates three moments of data; R is reflectivity, V is Doppler velocity and W is spectrum width. When the “R,V,W” symbols are used, this depicts the short range (48 nm/ 90 km) data sets. The first scan of the VCP is listed as having the moment “Long R”. This represents the long range reflectivity scan. This contiguous surveillance (i.e., Waveform Type 1) scan does not contain any Doppler moments.

The final column on the left half is the PRI. The PRI is inversely proportional to the Pulse Repetition Frequency (PRF). The long PRI time for scan 1 is used to gather reflectivity information at maximum range (460 km/248 nm). The remaining PRI values are all between 500-600 microseconds with the exception of scan 3 as part of the low elevation split cut.

The right side of Figure 8 contains details of VCP 90. In this volume, only 16 elevations will be processed. Hence, the elevation cut (EL Cut) will be internally derived by a process within the SPG and not taken directly from the TDWR radial header.

Different from the WSR-88D, not all of the elevation angles sequentially ascend. In this case, cut 2 is below cut 1. This will not be the same for all TDWRs but will occur with a high frequency across the country. As examples, the volume scan number (VS #) and the volume scan start time (VS Time) are 1 and 0, respectively. This designates that the VCP 90 will be represented to the SPG as one volume with no duplicate elevation. This will become important when discussing the hazardous mode VCP.

Finally, the waveform (WF) type uses the numerical designations found in the RDA to RPG ICD, Table XI, Volume Coverage Pattern. WF Type 1, contiguous surveillance will be used to represent the long range reflectivity. WF Type 3, contiguous Doppler without ambiguity resolution will be used to represent all other scans.

Native TDWR Monitor Mode				SPG Product Description Block				VCP
Scan No	Elv (deg)	Moments	PRI	VCP BWI	VS #	VS Time	EL Cut	WF Type
1	0.6	Long R	3066	90	e.g.,1	e.g., 0	1	1
2	0.5	R, V, W	598					
				90	1	0	2	3
3	0.5	R, V, W	838					
4	1.0	R, V, W	598	90	1	0	3	3
5	3.3	R, V, W	598	90	1	0	4	3
6	6.1	R, V, W	598	90	1	0	5	3
7	11.0	R, V, W	598	90	1	0	6	3
8	15.9	R, V, W	518	90	1	0	7	3
9	20.8	R, V, W	518	90	1	0	8	3
10	25.7	R, V, W	518	90	1	0	9	3
11	30.6	R, V, W	518	90	1	0	10	3
12	35.5	R, V, W	518	90	1	0	11	3
13	40.4	R, V, W	518	90	1	0	12	3
14	45.3	R, V, W	518	90	1	0	13	3
15	50.2	R, V, W	518	90	1	0	14	3
16	55.1	R, V, W	518	90	1	0	15	3
17	60.0	R, V, W	518	90	1	0	16	3

Figure 8 - VCP 90 for the Monitor Mode Scan Strategy (using BWI elevation angles). Note: the “e.g.,” appears by Volume Scan (VS)#, and the VS Time since they vary. Specific numbers are listed just as an example.

VCP 80 Description

Figure 9 provides a VCP 80 template for the TDWR hazardous mode scan strategy. VCP 80 is much more complex than VCP 90 since it consists of two "sub-volumes" in each scan-sequence and the low elevation base scan every fourth scan (approximately once per minute).

As with the example shown for VCP 90, the left side of Figure 9 represents what is being received from the TDWR. The bold horizontal line between cuts 13 and 14 represents a transition between the sub-volumes (see Figure 10 for a graphical representation of the sub-volume within hazardous mode).

Native TDWR Hazardous Mode				SPG Product Description Block				VCP
Scan No	Elv (deg)	Moments	PRI	VCP BWI	VS #	VS Time	EL Cut	WF Type
1	0.6	Long R	3066	80	e.g.,1	20	1	1
2	0.5	R, V, W	598					
				80	1	60	2	3
3	0.5	R, V, W	838					
4	1.0	R, V, W	598	80	1	60	3	3
5	3.3	R, V, W	598	80	1	60	4	3
6	6.6	R, V, W	598	80	1	60	5	3
7	0.5	R, V, W	598	80	1	140	6	3
8	10.0	R, V, W	598	80	1	60	7	3
9	13.4	R, V, W	598	80	1	60	8	3
10	19.4	R, V, W	518	80	1	60	9	3
11	0.5	R, V, W	598	80	1	220	10	3
12	28.1	R, V, W	518	80	1	60	11	3
13	42.0	R, V, W	518	80	1	60	12	3
14	3.3	R, V, W	598	80	1	280	13	3
15	0.5	R, V, W	598	80	1	280	14	3
16	6.6	R, V, W	598	80	1	280	15	3
17	10.0	R, V, W	598	80	1	280	16	3
18	13.4	R, V, W	598	80	1	280	17	3
19	0.5	R, V, W	598	80	1	380	18	3
20	19.4	R, V, W	518	80	1	280	19	3
21	28.1	R, V, W	518	80	1	280	20	3
22	42.0	R, V, W	518	80	1	280	21	3
23	0.5	R, V, W	598	80	1	460	22	3

Figure 9 - VCP 80 for the Hazardous Mode Scan Strategy (using BWI elevation angles). Note: the "e.g.," appears by the Volume Scan (VS)# since they may vary. Specific numbers are listed just as an example.

The right side of Figure 9 shows the structure of VCP 80. As with monitor mode, TDWR cuts 2 and 3 have been combined to generate VCP elevation 2. This leaves VCP 80 with a total of 22 scans. The waveform designations are the same. The volume sequence number indicates that to the SPG all of the elevations will be treated as one volume group.

However, the volume scan start time has a significant difference between the TDWR VCPs and WSR-88D VCPs. The volume scan start times change within the volume scan. This was done so that the SPG and AWIPS can discriminate between elevations that have the same angle in the same volume. This discrimination allows for AWIPS D2D to loop images such as 1-minute base scans of reflectivity or velocity. Hence, intra volume data scan times will be inserted in the volume scan start time field of elevations with duplicated elevation angles. The intent is to time link elevations that comprise the sub-volume scans, and to assign a unique time to the low level scans which are in-between the sub-volumes. For this reason, it may be easier to think of this time as a "Product Time".

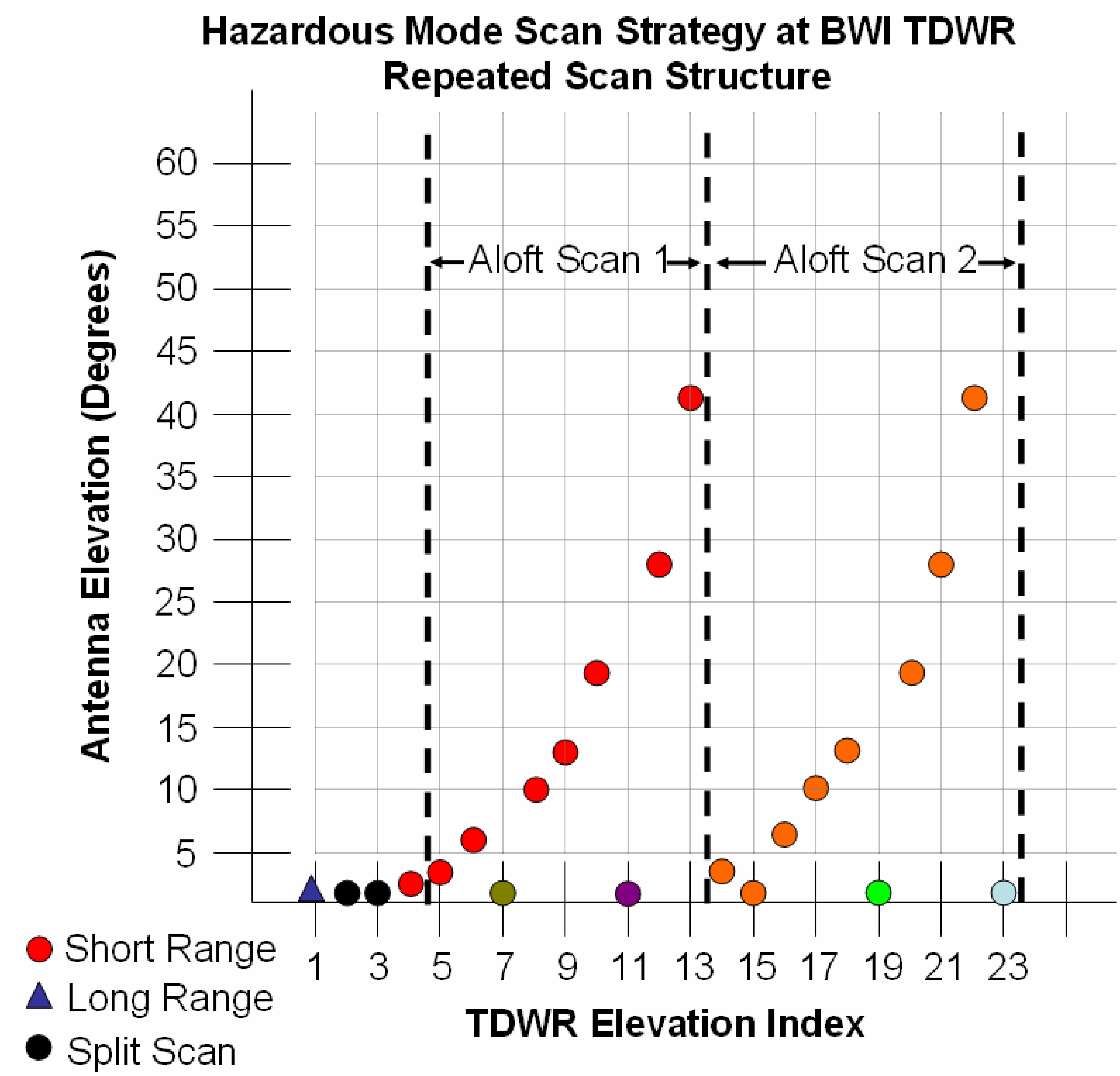

Figure 10 – Graphical depiction of VCP 80. The different colors represent changes in the internal volume start time associated with scans. The vertical axis represents the elevation angle in whole degrees. The horizontal axis represents the native TDWR elevation index.

Class I, Interface Control Document (ICD) Modifications

This portion of the document highlights changes that will be required to properly format AWIPS-compatible radar products using TDWR data at the resolutions selected by the NWS HQ Systems Engineering Center.

The TDWR contains data at resolutions much higher than what is found in the WSR-88D. Hence, to stay within the allocated storage for the statically allocated SPG internal base data structures, some of the resolutions and ranges have had to be modified. Table 4 provides this information. Please note, a future upgrade is planned which will allow the higher resolution reflectivity to be internally handled by the SPG. To avoid future compatibility problems with AWIPS, the SPG reflectivity products are provided at the future resolution of 150 m and 300m for the short and long range scans, respectively. This is achieved by taking SPG internal radials containing 460 or 300 bins and double reporting each bin to generate products containing 920 and 600 bins per radial.

Table 4 – TDWR SPG range and resolution translations

Product Type	Native Resolution	Native Range	#bins available	SPG Resolution	SPG Range	#bins used
Long Range Reflectivity	150 m from 0-135 km. 300 m from 135-460 km	460 km (248 nm)	1981 bins	600 m	276 km (149 nm)	460 bins
Short Range Reflectivity	150 m	90 km (48 nm)	600 bins	300 m	90 km (48 nm)	300 bins
Short Range Doppler	150 m	90 km (48 nm)	600 bins	150 m	90 km (48 nm)	600 bins

Changes from the Class I ICD are noted in red. Those data fields that are not changed, but are internally modified by the SPG software are colored in blue.

Table 5 –Message Codes for Products

CODE	NTR	PRODUCT NAME	RESOLUTION	RANGE	DATA LEVEL	MESSAGE FORMAT
180	1	Base Reflectivity Data Array	.08 x 1 Nmi x Deg	48	256	Radial Image
181	1	Base Reflectivity	.08 x 1 Nmi x Deg	48	16	Radial Image
182	2	Base Velocity Data Array	.08 x 1 Nmi x Deg	48	256	Radial Image
183	2	Base Velocity	.08 x 1 Nmi x Deg	48	16	Radial Image
185	3	Base Spectrum Width	.08 x 1 Nmi x Deg	48	8	Radial Image
186	1	Base Reflectivity Data Array	.16 x 1 Nmi x Deg	149	256	Radial Image
187	1	Base Reflectivity	.16 x 2 Nmi x Deg	149	16	Radial Image

Message Header Block

A new set of source IDs (Appendix A) and product message codes (Table 5) has been established for FAA radars.

Table 6 – Message Header Block

	MSB HALFWORD LSB	
MESSAGE HEADER BLOCK	MESSAGE CODE	01
	DATE OF MESSAGE	02
	TIME OF MESSAGE (MSW)	03
	TIME OF MESSAGE (LSW)	04
	LENGTH OF MESSAGE (MSW)	05
	LENGTH OF MESSAGE (LSW)	06
	SOURCE ID	07
	DESTINATION ID	08
	NUMBER OF BLOCKS	09

Table 6 (cont) - Message Header Block Description

HALF WORD	FIELDNAME	TYPE	UNITS	RANGE	PRECISION/ ACCURACY	REMARKS
01	Message Code	INT*2	N/A	-131 to -16, 0 to +211	N/A	NEXRAD Message Code defined in Table II. See Appendix A
02	Date of Message	INT*2	Julian Date	1 to 32,767	1	Modified Julian Date at time of transmission (number of days since 1 January 1970, where 1=1 January 1970). To obtain actual Julian Date, add 2,440,586.5 to the modified date
03-04	Time of Message	INT*4	Seconds	0 to 86,399	1	Number of seconds after midnight, Greenwich Mean Time (GMT). Modified in VCP 80
05-06	Length of Message	INT*4	N/A	18 to 409856	1	Number of bytes in message including header
07	Source ID	INT*2	N/A	0 to 3045	1	Source (originators') ID of the sender. See Appendix A

08	Destination ID	INT*2	N/A	0 to 999	1	Destination ID (receivers') for message transmission
09	Number Blocks	INT*2	N/A	1 to 51	1	Header Block plus the Product Description Blocks in message

Product Description Block

To properly accommodate TDWR products, the following modifications must be made to the Product Description Block (Table 7):

a. Halfword 16: Product Code – New product codes for the TDWR
b. Halfword 17: Operational Mode – The TDWR will only provide "Precipitation/Severe Weather" Operational Mode from the SPG
c. Halfword 18: VCP – The TDWR has designated VCPs different from those found in the WSR-88D

Note: Red designates a change to the ICD is required. Blue designates that these fields will be set internally by pre-processors or algorithms and not the native data stream.

Table 7 – The Product Description Block

PRODUCT	10	(-1) BLOCK DIVIDER
DESCRIPTION	11	LATITUDE OF RADAR (MSW)
BLOCK	12	(LSW)
	13	LONGITUDE OF RADAR (MSW)
	14	(LSW)
	15	HEIGHT OF RADAR
	16	PRODUCT CODE
	17	OPERATIONAL MODE
	18	VOLUME COVERAGE PATTERN
	19	SEQUENCE NUMBER
	20	VOLUME SCAN NUMBER
	21	VOLUME SCAN DATE
	22	VOLUME SCAN START (MSW)
	23	TIME

	(LSW)		
24	PRODUCT GENERATION DATE		
25	PRODUCT GENERATION (MSW)		
	TIME (LSW)		
27	PRODUCT DEPENDENT (P1)		(SEE TABLE V)
28	PRODUCT DEPENDENT (P2)		(SEE TABLE V)
29	ELEVATION NUMBER		
30	PRODUCT DEPENDENT (P3)		(SEE TABLE V)
31	DATA LEVEL 1 THRESHOLD		(SEE NOTE, SHEET 11)
32	DATA LEVEL 2 THRESHOLD		
33	DATA LEVEL 3 THRESHOLD		
34	DATA LEVEL 4 THRESHOLD		
35	DATA LEVEL 5 THRESHOLD		
36	DATA LEVEL 6 THRESHOLD		
37	DATA LEVEL 7 THRESHOLD		
38	DATA LEVEL 8 THRESHOLD		
39	DATA LEVEL 9 THRESHOLD		
40	DATA LEVEL 10 THRESHOLD		
41	DATA LEVEL 11 THRESHOLD		
42	DATA LEVEL 12 THRESHOLD		
43	DATA LEVEL 13 THRESHOLD		
44	DATA LEVEL 14 THRESHOLD		(SEE NOTE, SHEET 11)
45	DATA LEVEL 15 THRESHOLD		
46	DATA LEVEL 16 THRESHOLD		
47	PRODUCT DEPENDENT (P4)		(SEE TABLE V)
48	“ (P5)		
49	“ (P6)		
50	“ (P7)		
51	“ (P8)		
52	“ (P9)		
53	“ (P10)		
54	VERSIONS	SPOT BLANK	
55	OFFSET TO GRAPHIC (MSW)		
56	(LSW)		
57	OFFSET TO GRAPHIC (MSW)		
58	(LSW)		
59	OFFSET TO TABULAR (MSW)		
60	(LSW)		

Table 7 (cont) - Product Description Block – Field Description

HALFWORD	FIELDNAME	TYPE	UNITS	RANGE	PRECISION/ ACCURACY	REMARKS
10	Block Divider	INT*2	N/A	-1	N/A	Integer value of -1 used to delineate the header from the Product Description Block
11 - 12	Latitude of Radar	INT*4	Degrees	-90 to +90	0.001	North (+) or South (-) of the Equator
13 - 14	Longitude of Radar	INT*4	Degrees	-180 to +180	0.001	East (+) or West (-) of the Prime Meridian
15	Height of Radar	INT*2	Feet	-100 to +11000	1	Feet above mean sea level
16	Product Code	INT*2	N/A	16 to 187, -16 to -131	N/A	Internal NEXRAD product code of weather product being transmitted Table 5
17	Operational Mode	INT*2	N/A	0 to 2	N/A	0 = Maintenance 1 = Clean Air 2 = Precipitation/ Severe Weather (only 2)
18	Volume Coverage Pattern	INT*2	N/A	1 to 767	1	RDA volume coverage pattern for the scan strategy being used – TDWR VCPs
19	Sequence Number	INT*2	N/A	-13, 0 to 32767	1	Sequence number of the request that generated the product (Refer to Figure 3-4). For products generated by an Alert Condition, sequence number = -13

HALFWORD	FIELDNAME	TYPE	UNITS	RANGE	PRECISION/ ACCURACY	REMARKS
20	Volume Scan Number	INT*2	N/A	1 to 80	1	Counter, recycles to one (1) every 80 volume scans
21	Volume Scan Date	INT*2	Julian Date	1 to 32767	1	Modified Julian Date; integer number of days since 1 Jan 1970
22 - 23	Volume Scan Start Time	INT*4	Seconds GMT	0 to 86399	1	Number of seconds after midnight, Greenwich Mean Time (GMT)
24	Generation Date of Product	INT*2	Julian Date	1 to 32767	1	Modified Julian Date as above
25 - 26	Generation Time of Product	INT*4	Seconds GMT	0 to 86399	1	Number of seconds after midnight, Greenwich Mean Time (GMT)
27 - 28	---PRODUCT DEPENDENT AS PER TABLE V---					
29	Elevation Number	INT*2	N/A	0 to 22	1	Elevation number within volume scan for elevation based product 0 for volume based products.
30 - 53	---PRODUCT DEPENDENT AS PER TABLE V---					
54	Version	INT*1	N/A	0 to 255	1	If the message is product data, the upper byte is the version number of the product. The original format of a product will be

HALFWORD	FIELDNAME	TYPE	UNITS	RANGE	PRECISION/ ACCURACY	REMARKS
						version 0. (Note 2)
54	Spot Blank	INT*1	N/A	0 to 1	1	If the message is product date, the lower byte is: 1 = Spot Blank ON 2 = Spot Blanking if OFF
55 - 56	Offset to Symbology	INT*4	Halfwords	0 to 80000	1	Number of halfwords from the top of message (message code field in header) to the -1 divider of each block listed. If the offset is zero (0), the block is not part of the product in question
57 - 58	Offset to Graphic	INT*4	Halfwords	0 to 80000	1	Same as above to Graphic Block (NOTE: For Product 62, this will point to the Cell Trend data)
59 - 60	Offset to Tabular	INT*4	Halfwords	0 to 80000	1	Same as above to Tabular Block

Product Symbology Block

No modifications are required to support TDWR products.

Table 8 – Product Symbology Block

PRODUCT	(-1) BLOCK DIVIDER	
SYMBOLOGY	BLOCK ID (1)	
BLOCK	LENGTH OF BLOCK (MSW)	
	(LSW)	
	NUMBER OF LAYERS	
	(-1) LAYER DIVIDER	
	LENGTH OF DATA LAYER (MSW)	
	(LSW)	
	DISPLAY DATA PACKETS	SEE FIGURES 3-6 THRU 3-14
	• • •	
	(-1) LAYER DIVIDER	
	LENGTH OF DATA LAYER (MSW)	
	(LSW)	
	DISPLAY DATA PACKETS	SEE FIGURES 3-6 THRU 3-14

Table 8 (cont) Product Symbology Block – Field Descriptions

FIELDNAME	TYPE	UNITS	RANGE	PRECISION/ ACCURACY	REMARKS
Block Divider	INT*2	N/A	-1	N/A	Integer value of -1 used to delineate the Product Description from the Product Symbology Block
Block ID	INT*2	N/A	1	N/A	Constant value of 1 which identifies this block
Length of Block	INT*4	Bytes	1 to 80000	1	Length of block in bytes (includes preceding divider and block id)
Number of Layers	INT*2	N/A	1 to 15	1	Number of data layers contained in this block (see Note 2)
Layer Divider	INT*2	N/A	-1	N/A	Integer value of -1 used to delineate one data layer from another
Length of Data Layer	INT*4	N/A	1 to 80000	1	Length of data layer (in bytes) not including layer divider and length field
Display Data Packets	N/A	N/A	N/A	N/A	See Figures 3-6 through 3-14

Data Packets for the SPG

Radial Packet 16

No modifications are required to support TDWR products

Table 9 - Digital Radial Data Array (Sheet 1 of 2)

	MSB HALFWORD	LSB
	PACKET CODE (=16)	
	INDEX OF FIRST RANGE BIN	
	NUMBER OF RANGE BINS	
	I CENTER OF SWEEP	
	J CENTER OF SWEEP	
	RANGE SCALE FACTOR	
	NUMBER OF RADIALS	
REPEAT FOR EACH ROW	NUMBER OF BYTES IN RADIAL	
	RADIAL START ANGLE	
	RADIAL DELTA ANGLE	
	LEVEL (0)	LEVEL (1)
	LEVEL (2)	LEVEL (3)
	•	•
	•	•
	LEVEL (N-1)	LEVEL (N)

Digital Radial Data Array Packet (Sheet 1 of 2)

FIELDNAME	TYPE	UNITS	RANGE	PRECISION/ ACCURACY	REMARKS
Packet Code	INT*2	N/A	16	N/A	Packet Type 16
Index of First Range Bin	INT*2	N/A	0 to 230	1	Location of first range bin
Number of Range Bins	INT*2	N/A	0 to 230	1	Number of range bins comprising a radial
I Center of Sweep	INT*2	Km/4	-2048 to +2047	1	I coordinate of center of sweep
J Center of Sweep	INT*2	Km/4	-2048 to +2047	1	J coordinate of center of sweep
Range Scale Factor	Scaled Integer	N/A	.001 to 1.000	.001	Cosine of elevation angle
Number of Radials	INT*2	N/A	1 to 400	1	Total number of radials in product
Number of Bytes in Radial	INT*2	N/A	1 to 920	1	Number of bytes of 8-bit data level values per radial
Radial Start Angle	Scaled Integer	Degrees	0.0 to 359.9	.1	Starting angle at which radial data was collected; Scan is always clockwise
Radial Delta Angle	Scaled Integer	Degrees	0.0 to 2.0	1	Delta angle from previous radial
Level (0)	1 Byte	N/A	0 to 255	1	8-bit data level code. (See Note 1 of Figure 3-6 Sheet 11 of 14)

16 Level Run Length Encoded Packet AF1F

No modifications are required to support TDWR products

Table 10 – Radial Packet AF1F (16-level)

	MSB	HALFWORD		LSB	
	A	F	1	F	PACKET CODE
	INDEX OF FIRST RANGE BIN				
	NUMBER OF RANGE BINS				
	I CENTER OF SWEEP				
	J CENTER OF SWEEP				
	SCALE FACTOR (230 / # OF RANGE BINS)				
	NUMBER OF RADIALS				
REPEAT FOR EACH RADIAL	NUMBER OF RLE HALFWORDS IN RADIAL				
	RADIAL START ANGLE				
	RADIAL ANGLE DELTA				
	RUN (0)	COLOR CODE (0)	RUN (1)	COLOR CODE (1)	
	RUN (2)	COLOR CODE (2)	RUN (3)	COLOR CODE (3)	
	•	•	•		
	•	•	•		
	RUN (N)	COLOR CODE (N)	0000	0000	

FIELDNAME	TYPE	UNITS	RANGE	PRECISION/ ACCURACY	REMARKS
Packet Code	INT*2	N/A	AF1F (Hex)	N/A	Packet Type X7AF1F7
Index of First Range Bin	INT*2	N/A	0 to 460	1	Location of first range bin
Number of Range Bins	INT*2	N/A	1 to 460	1	Number of range bins comprising a radial
I Center of Sweep	INT*2	Km/4	-2048 to +2047	1	I coordinate of center of sweep
J Center of Sweep	INT*2	Km/4	-2048 to +2047	1	J coordinate of center of sweep
Scale Factor	Scaled Integer	Pixels	.001 to 8.000	.001	Number of pixels per range bin
Number of Radials	INT*2	N/A	1 to 400	1	Total number of radials in products
Number of RLE Halfwords in Radial	INT*2	Halfword	1 to 230	1	Number of RLE (Run Length Encoded) 16-bit halfwords per radial
Radial Start Angle	Scaled Integer	Degrees	0.0 to 359.9	.1	Starting angle at which radial data was collected; Scan is always in Clockwise direction
Radial Angle Delta	Scaled Integer	Degrees	0.0 to 2.0	.1	Radial angle data
Run(0)	4 Bit INT	N/A	0 to 15	1	4-bit run code
Color Code(0)	4 Bit INT	N/A	0 to 15	1	4-bit color level

Product Specifications Document Modifications

Note: Red designates a required change relative to the WSR-88D version of the ICD.

1 TDWR REFLECTIVITY (R AND DR)

SSS Product Description

"This product shall provide the reflectivity data displayable as an image[1] and formatted as a data array. For the image version, variations of the product shall be organized to provide various areas of coverage and display resolutions, while the data array version will provide the highest resolution available for the entire coverage area. Both versions will be limited to the lowest 70,000 feet AGL of the atmosphere. The product shall be generated for any azimuth scan at a single elevation angle based on user requirements. ~~Each scan shall be updated once per volume scan time.[2]~~ Multiple scans for the same elevation may be generated within the same volume depending on the operational mode. For the image version, each product shall be available for ~~both 8 and~~ 16 reflectivity data levels, while 256 reflectivity data levels will be provided in the data array version. Each product shall include annotations for the product name, radar ID, time and date of scan, data level code, elevation angle, maximum data value (dBZ), radar position, radar elevation above MSL, and radar operational mode. ~~BZIP2 compression shall be used for the transmission of these products.~~"

Note: Radar ID's for FAA radars can be found in Appendix A.

Display Format

The product is displayable in full- or quarter-screen format (see Appendix B).

1.1.1 Data Levels

~~For the image version, the range of data level values (dBZ) varies with operational mode, area climatology and season, and with NEXRAD system (or agency) adaptation data.~~ The range of reflectivity supported by the TDWR RDA is ~~-32 to +95~~ -30 to +80 dBZe.

1.1.2 Color Level Code Tables

The color level code used for display of the image version of reflectivity is NEXRAD (or agency) system adaptation data. Only precipitation mode color tables will be used with TDWR data. ~~Some examples of color tables for both Modes A and B are listed.~~ With the exception of the end points, the lower value of the range is assigned to the individual colors displayed. The range of values for each is also indicated.

\- - - - - - -

"[1]Defines the form of presentation on a graphic display; not necessarily the form of transmission."

"[2]~~Defined in Appendix B"~~

Color Level Codes for TDWR VCPs

~~Precipitation Mode~~

16-Level Code	Display dBZ	Range dBZ	Color Levels Code	Color
0	ND	SNR<TH OR dBZ<5	(00 00 00)	Black
1	5	5≤dBZ<10	(9C 9C 9C)	medium gray
2	10	10≤dBZ<15	(76 76 76)	dark gray
3	15	15≤dBZ<20	(FF AA AA)	light pink
4	20	20≤dBZ<25	(EE 8C 8C)	medium pink
5	25	25≤dBZ<30	(C9 70 70)	dark pink
6	30	30≤dBZ<35	(00 FB 90)	light green
7	35	35≤dBZ<40	(00 BB 00)	medium green
8	40	40≤dBZ<45	(FF FF 70)	light yellow
9	45	45≤dBZ<50	(D0 D0 60)	dark yellow
A	50	50≤dBZ<55	(FF 60 60)	light red
B	55	55≤dBZ<60	(DA 00 00)	medium red
C	60	60≤dBZ<65	(AE 00 00)	dark red
D	65	65≤dBZ<70	(00 00 FF)	Blue
E	70	70≤dBZ<75	(FF FF FF)	White
F	75	75≤dBZ	(E7 00 FF)	Purple

~~Color Level Codes~~

~~Clear Air Mode~~

~~16-Level Code~~	~~Display dBZ~~	~~Range dBZ~~	~~Color Levels Code~~	~~Color~~
~~0~~	~~ND~~	~~SNR<TH or dBZ<-28~~	~~(00 00 00)~~	~~Black~~
~~1~~	~~-28~~	~~-28≤dBZ<-24~~	~~(9C 9C 9C)~~	~~medium gray~~
~~2~~	~~-24~~	~~-24≤dBZ<-20~~	~~(76 76 76)~~	~~dark gray~~
~~3~~	~~-20~~	~~-20≤dBZ<-16~~	~~(FF AA AA)~~	~~light pink~~
~~4~~	~~-16~~	~~-16≤dBZ<-12~~	~~(EE 8C 8C)~~	~~medium pink~~
~~5~~	~~-12~~	~~-12≤dBZ<-8~~	~~(C9 70 70)~~	~~dark pink~~
~~6~~	~~-8~~	~~-8≤dBZ<-4~~	~~(00 FB 90)~~	~~light green~~
~~7~~	~~-4~~	~~-4≤dBZ<0~~	~~(00 BB 00)~~	~~medium green~~
~~8~~	~~0~~	~~0≤dbZ<+4~~	~~(FF FF 70)~~	~~light yellow~~
~~9~~	~~+4~~	~~+4≤dBZ<+8~~	~~(D0 D0 60)~~	~~dark yellow~~
~~A~~	~~+8~~	~~+8≤dBZ<+12~~	~~(FF 60 60)~~	~~light red~~
~~B~~	~~+12~~	~~+12≤dBZ<+16~~	~~(DA 00 00)~~	~~medium red~~
~~C~~	~~+16~~	~~+16≤dBZ<+20~~	~~(AE 00 00)~~	~~dark red~~
~~D~~	~~+20~~	~~+20≤dBZ<+24~~	~~(00 00 FF)~~	~~Blue~~
~~E~~	~~+24~~	~~+24≤dBZ<+28~~	~~(FF FF FF)~~	~~White~~
~~F~~	~~+28~~	~~+28≤dBZ~~	~~(E7 00 FF)~~	~~Purple~~

~~Precipitation Mode and Clear Air Mode~~

~~8-Level Code~~	~~Display dBZ~~	~~Range dBZ~~	~~Color Levels~~	
			~~Code~~	~~Color~~
~~0~~	~~ND~~	~~SNR<TH or dBZ<5~~	~~(00 00 00)~~	~~Black~~
~~1~~	~~5~~	~~5≤dBZ<18~~	~~(FF AA AA)~~	~~light pink~~
~~2~~	~~18~~	~~18≤dBZ<30~~	~~(C9 70 70)~~	~~dark pink~~
~~3~~	~~30~~	~~30≤dBZ<41~~	~~(00 BB 00)~~	~~medium green~~
~~4~~	~~41~~	~~41≤dBZ<46~~	~~(FF FF 70)~~	~~light yellow~~
~~5~~	~~46~~	~~46≤dBZ<50~~	~~(DA 00 00)~~	~~medium red~~
~~6~~	~~50~~	~~50≤dBZ<57~~	~~(00 00 FF)~~	~~Blue~~
~~7~~	~~57~~	~~57≤dBZ~~	~~(FF FF FF)~~	~~White~~

1.1.3 Range/Data Resolution

Both the image and data array products will be available for the range/resolution combinations as indicated in all operational modes.

Product Range	Coverage Area (nmi Radius)	Resolution (nmi x deg)	Product Center
Short Range REFL	0 to ~~124~~ 48	~~0.54~~ 0.08 x 1	Radar location
Long Range REFL	0 to ~~248~~ 149	~~1.1~~ 0.16 x 1	Radar location
~~Long Range REFL~~	~~0 to 248~~	~~2.2 x 1~~	~~Radar location~~

Annotations

1.1.4 Alphanumeric

Standard Annotations (Appendix A, I(A))
Elevation Angle
Data Level Code
Maximum Data Value Detected

1.1.5 Special Symbols

None defined

Product Interaction

All overlay products are displayable on this product:
None defined
~~– Combined Shear Contour~~
~~– Hail Index~~
~~– Mesocyclone~~
~~– Severe Weather Probability~~
~~– Storm Tracking Information~~
~~– Tornado Vortex Signature.~~

2 MEAN RADIAL VELOCITY (V AND DV)

2.1 SSS Product Description

"This product shall provide the mean radial velocity data both displayable as an image and formatted as a data array. For the image version, variations of the product shall be organized to provide various areas of coverage and display resolution, while the data array version will provide the highest resolution available for the entire radar coverage area. Both versions will be limited to lowest 70,000 feet AGL of the atmosphere. The product shall be generated for any azimuth scan at a single elevation angle based on user requirements. ~~Each scan shall be updated once per volume scan time.~~ Each scan shall be updated for each elevation consisting of TDWR short range data. This may consist of more than one scan at the same angle for a volume. For the image version, each product shall include ~~both 8 and~~ 16 mean radial velocity data levels, while 256 velocity data levels will be provided in the data array version. Each product shall include annotations for the product name, radar ID, time and date of scan, data level code, elevation angle, maximum data value detected (knots, positive and negative), radar position, radar elevation above MSL, and radar operational mode. ~~BZIP2 compression shall be used for the transmission of these products~~."

Note 1: Radar ID's for FAA can be found in Appendix A.
Note 2 Depending on the setting at the SPG, TDWR Doppler velocities can be truncated from their native +/- 80 m/s range (accuracy of 1 m/s, precision of 0.25 m/s) down to +/- 63 m/s (accuracy of 0.5 m/s, precision of 0.25 m/s) for these products.

2.2 Display Format

The product is displayable in full- or quarter-screen format (see Appendix B).

2.2.1 Data Levels

For the image version, the range of mean radial velocity values will vary ~~with operational mode and~~ with NEXRAD system (or agency) adaptation data. The data thresholds are site adaptable. ~~The range of values used is a function of meteorological mode and/or operator option.~~. The SPG will generate velocity products in accordance with either Velocity Increment (aka, Doppler Velocity resolution mode, RDA/RPG ICD, Message 1, byte position 42-43). When the SPG is set to the 0.5 m/s mode, the velocity will be truncated to -63.5/+64 m/s. Since the TDWR provides dealiased velocity to +/- 80 m/s, the default SPG setting will be set to the 1.0 m/s mode.

2.2.2 Color Level Code Tables

The color level code used for display of the image version of mean radial velocity is NEXRAD system (or agency) adaptation data. Examples for a currently defined color table~~s~~ ~~are~~ is shown. With the exception of end point values the lower value of the velocity range is assigned to the individual colors displayed. The range of values for each is also indicated.

Color Level Codes

16-Level Code	Display Knots	Range knots	Color Levels Code	Color
0	ND	SNR<TH	(00 00 00)	black
1	-64	-64≥knots	(00 E0 FF)	light blue
2	-50	-50≥knots>-64	(00 80 FF)	medium blue
3	-36	-36≥knots>-50	(32 00 96)	dark blue
4	-26	-26≥knots>-36	(00 FB 90)	light green
5	-20	-20≥knots>-26	(00 BB 99)	medium green
6	-10	-10≥knots>-20	(00 8F 00)	dark green
7	-1	0≥knots>-10	(CD C9 9F)	light gray
8	0	0≤knots<+10	(76 76 76)	dark gray
9	+10	+10≤knots<+20	(F8 87 00)	medium orange
A	+20	+20≤knots<+26	(FF CF 00)	medium yellow
B	+26	+26≤knots<+36	(FF FF 00)	yellow
C	+36	+36≤knots<+50	(AE 00 00)	dark red
D	+50	+50≤knots<+64	(D0 70 00)	medium brown
E	+64	+64≤knots	(FF 00 00)	bright red
F	RF	RF	(77 00 7D)	dark purple

~~8-Level Code~~	~~Display Knots~~	~~Range knots~~	~~Color Levels Code~~	~~Color~~
~~0~~	~~ND~~	~~SNR<TH~~	~~(00 00 00)~~	~~black~~
~~1~~	~~-10~~	~~-10≥knots~~	~~(00 E0 FF)~~	~~light blue~~
~~2~~	~~-5~~	~~-5≥knots>-10~~	~~(00 BB 00)~~	~~medium green~~
~~3~~	~~-1~~	~~0≥knots>-5~~	~~(00 8F 00)~~	~~dark green~~
~~4~~	~~0~~	~~0≤knots<+5~~	~~(F8 87 00)~~	~~medium orange~~
~~5~~	~~+5~~	~~+5≤knots<+10~~	~~(FF CF 00)~~	~~medium yellow~~
~~6~~	~~+10~~	~~+10≤knots~~	~~(FF 00 00)~~	~~bright red~~
~~7~~	~~RF~~	~~RF~~	~~(77 00 7D)~~	~~dark purple~~

2.2.3 Range/Data Resolution

The image products will be available for the range/resolution combinations as indicated below. ~~Displayed values for lower resolution products are chosen by selecting every other bin value (0.27 nmi resolution) and every fourth bin value (0.54 nmi resolution).~~

Coverage Area (nmi Radius)	Resolution (nmi x deg)	Product Center
0 to ~~32~~ 48	~~0.13~~ 0.08 x 1	Radar location
~~0 to 62~~	~~0.27 x 1~~	~~Radar location~~
~~0 to 124~~	~~0.54 x 1~~	~~Radar location~~

The data array product will be available for the range/resolution as indicated.

Coverage Area (nmi)	Resolution (nmi x deg)	Product Center
0 to ~~124~~ 48	~~0.13~~ 0.08 x 1	Radar location

2.3 Annotations

2.3.1 Alphanumeric

Standard Annotations (Appendix A, I(A))
Elevation Angle
Data Level Code
Maximum Data Value Detected (both positive and negative)

2.3.2 Special Symbols

None defined

2.4 Product Interaction

All overlay products are displayable on this product:
None Defined

- ~~Combined Shear Contour~~
- ~~Hail Index~~
- ~~Mesocyclone~~
- ~~Severe Weather Probability~~
- ~~Storm Tracking Information~~
- ~~Tornado Vortex Signature.~~

3 SPECTRUM WIDTH (SW)

3.1 SSS Product Description

"This product shall provide the radial velocity spectrum width data displayable as an image. Variations of the product shall be organized to provide various areas of coverage and display resolutions. The product shall be generated for any azimuth scan at a single elevation angle based on user requirements. Each scan shall be updated when TDWR short range data are available. ~~Each scan shall be updated once per volume scan time.~~ Each product shall be available for 8 spectrum width data levels. Each product shall include annotations for the product name, radar ID, time and date of scan, data level code, elevation angle, maximum data value detected (knots), radar position, radar elevation above MSL, and radar operational mode. BZIP2 compression shall be used for the transmission of these products."

Note: Radar ID's for FAA radars can be found in Appendix A.

3.2 Display Format

The product is displayable in full- or quarter-screen format (see Appendix B).

<u>3.2.1 Data Levels</u>

The range of spectrum width data values displayed is from 0 to 20 kts. Any levels exceeding 20 kts will be truncated to 20 kts.

<u>3.2.2 Color Level Code Tables</u>

The color level code used for display of spectrum width is NEXRAD system (or agency) adaptation data. The currently defined color table for spectrum width is listed.

8-Level Code	Display knots	Range knots	Color Levels Code	Color
0	ND	SNR<TH	(00 00 00)	black
1	0	knots<4	(76 76 76)	dark gray
2	4	4≤knots<8	(9C 9C 9C)	medium gray
3	8	8≤knots<12	(00 BB 00)	medium green
4	12	12≤knots<16	(FF 00 00)	bright red
5	16	16≤knots<20	(D0 70 00)	medium brown
6	20	20≤knots	(FF FF 00)	yellow
7	RF	RF	(77 00 7D)	dark purple

3.2.3 Range/Data Resolution

The products will be available for the range/resolution combination as indicated below. ~~Displayed values for lower resolution products are chosen by selecting every other bin value (0.27 nmi resolution) and every fourth bin value (0.54 nmi resolution).~~

Coverage Area (nmi Radius)	Resolution (nmi x deg)	Product Center
0 to ~~32~~ 48	~~0.13~~ 0.08 x 1	Radar location
~~0 to 62~~	~~0.27 x 1~~	~~Radar location~~
~~0 to 124~~	~~0.54 x 1~~	~~Radar location~~

3.3 Annotations

3.3.1 Alphanumeric

Standard Annotations (Appendix A, I(A))
Elevation Angle
Data Level Code
Maximum Data Value Detected

3.3.2 Special Symbols

None defined

3.4 Product Interaction

All overlay products are displayable on this product:
None Defined

- ~~Combined Shear Contour~~
- ~~Hail Index~~
- ~~Mesocyclone~~
- ~~Severe Weather Probability~~
- ~~Storm Tracking Information~~
- ~~Tornado Vortex Signature~~.

Appendix

Table A1 – Listing of NWS assigned identifiers for TDWR radars, their affiliated airports, the SPG source ID and associated WFO.

TDWR ID	Location (and affiliated airport)	Source ID	NWS WFO
TADW	Washington ,D.C.(Andrews AFB, MD	3001	LWX
TATL	Atlanta, GA	3002	FFC
TBNA	Nashville, TN	3003	OHX
TBOS	Boston, MA	3004	BOX
TBWI	Baltimore, MD	3005	LWX
TCLE	Cleveland, OH	3006	CLE
TCLT	Charlotte, NC	3007	GSP
TCMH	Columbus, OH	3008	ILN
TCVG	Cincinnati, OH	3009	ILN
TDAL	Dallas, TX (Love Field)	3010	FWD
TDAY	Dayton, OH	3011	ILN
TDCA	Washington, D.C. (National)	3012	LWX
TDEN	Denver, CO	3013	BOU
TDFW	Dallas/Fort Worth, TX	3014	FWD
TDTW	Detroit, MI	3015	DTX
TEWR	Newark, NJ	3016	OKX
TFLL	Fort Lauderdale, FL	3017	MFL
THOU	Houston, TX (Hobby)	3018	HGX
TIAD	Dulles, VA	3019	LWX
TIAH	Houston, TX (Intercontinental)	3020	HGX
TICT	Wichita, KS	3021	ICT
TIND	Indianapolis, IN	3022	IND
TJFK	New York City, NY (Kennedy)	3023	OKX
TLAS	Las Vegas, NV	3024	VEF
TMCI	Kansas City, MO	3025	EAX
TMCO	Orlando, FL	3026	MLB
TMDW	Chicago, IL (Midway)	3027	LOT
TMEM	Memphis, TN	3028	MEG
TMIA	Miami, FL	3029	MFL
TMKE	Milwaukee, WI	3030	MKX
TMSP	Minneapolis, MN	3031	MPX
TMSY	New Orleans, LA	3032	LIX
TOKC	Oklahoma City, OK	3033	OUN
TORD	Chicago, IL (O'Hare)	3034	LOT
TPBI	West Palm Beach, FL	3035	MFL
TPHL	Philadelphia, PA	3036	PHI
TPHX	Phoenix, AZ	3037	PSR
TPIT	Pittsburgh, PA	3038	PBZ
TRDU	Raleigh, NC	3039	RAH
TSDF	Louisville, KY	3040	LMK
TSJU	San Juan, PR	3041	SJU
TSLC	Salt Lake City, UT	3042	SLC
TSTL	St. Louis, MO	3043	LSX
TTPA	Tampa, FL	3044	TBW
TTUL	Tulsa, OK	3045	TSA

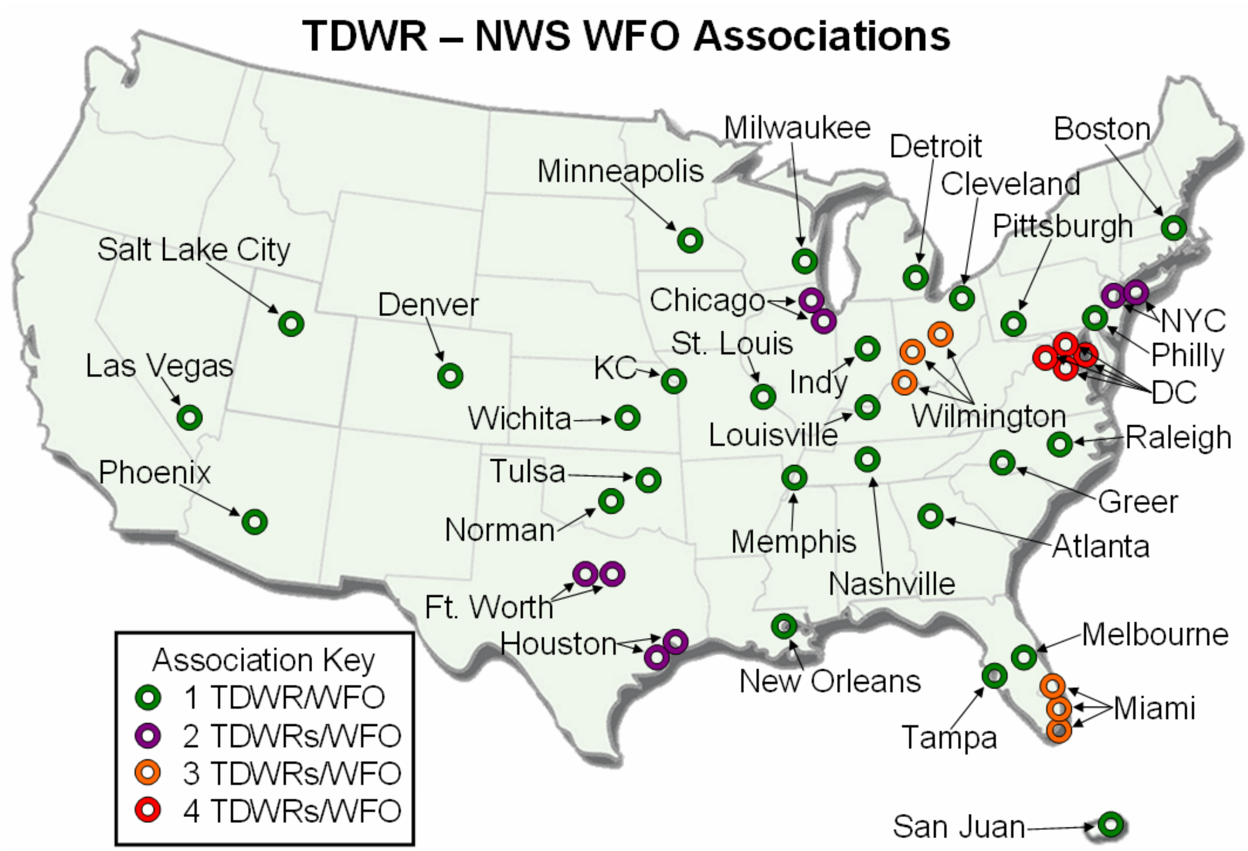

Figure A1 – TDWR/NWS WFO Association map

Figure A2 Altitude of the Maximum Unambiguous Range in Hazardous Mode (all 45 TDWRs)

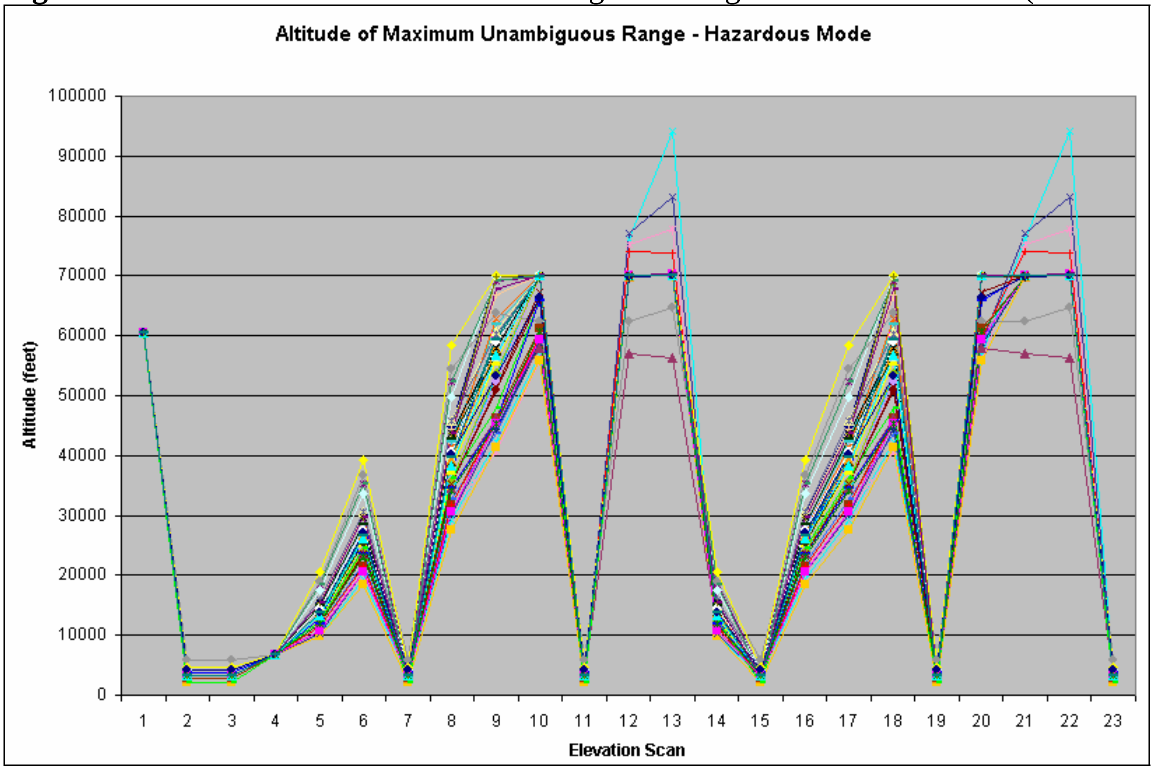

Figure A3 Maximum Unambiguous Range in Hazardous Mode (all 45 TDWRs/Short Range)

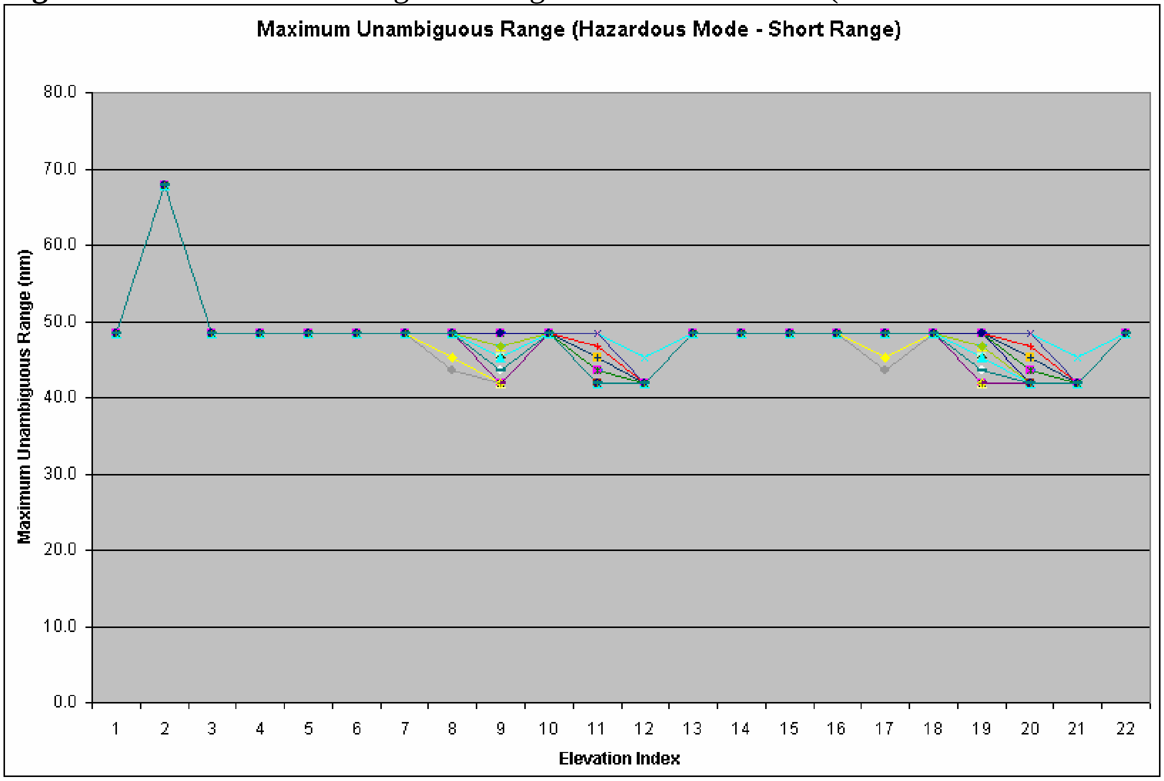

Figure A4 Nyquist Velocity in Hazardous Mode (all 45 TDWRs)

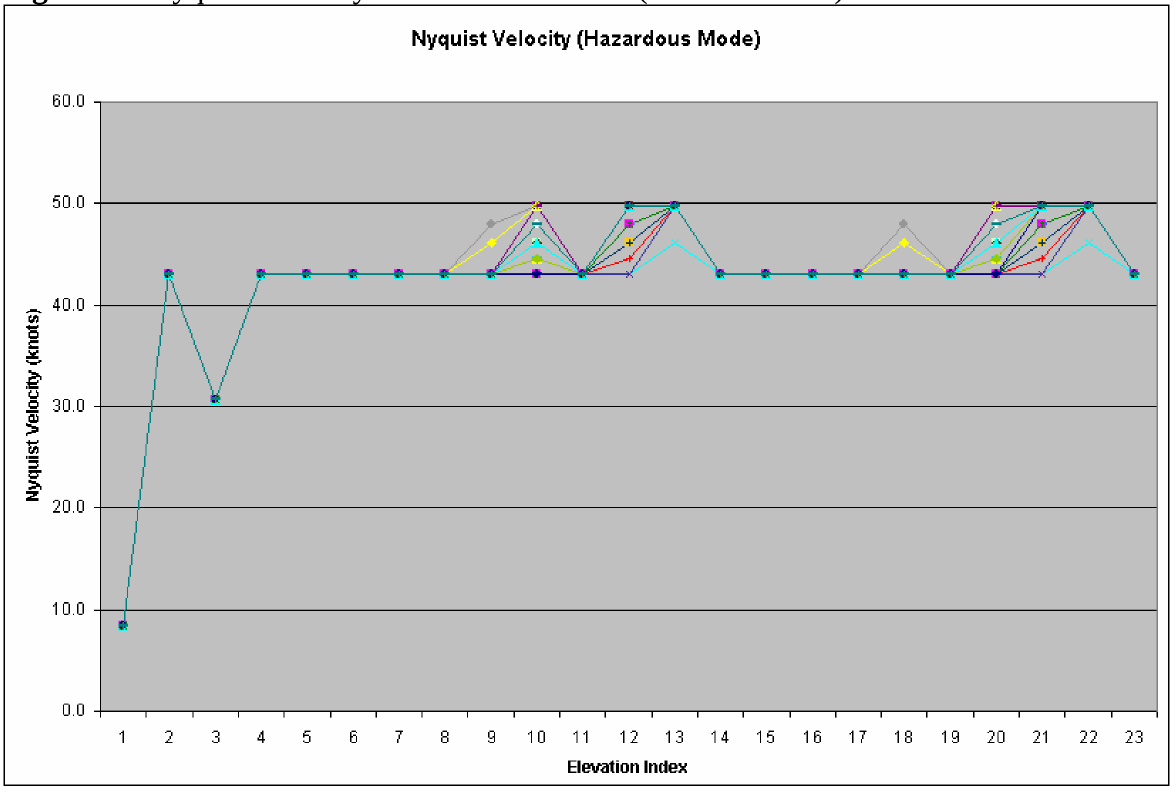

Figure A5 Pulse Repetition Frequencies in Hazardous Mode (all 45 TDWRs)

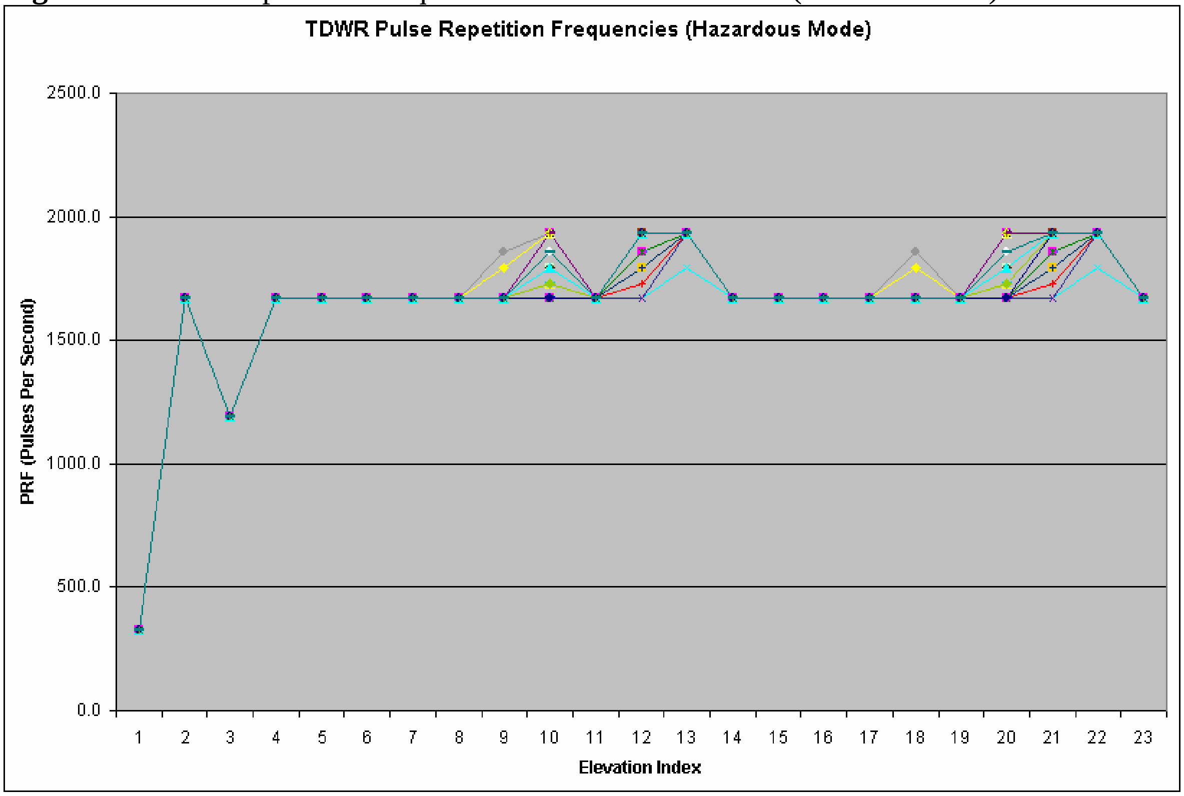

Figure A6 Number of Valid Bins per Radial in Hazardous Mode (all 45 TDWRs)